COMPUTERIZED MANAGEMENT TOOLS FOR USE IN THE ANALYSIS OF AUTODIN AUTOMATIC SWITCHING CENTERS AND ASSOCIATED TRIBUTARIES

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THESIS

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Computerized Management Tools for Use In The Analysis of AUTODIN Automatic Switching Centers and Associated Tributaries

by

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ABSTRACT

A general AUTODIN and Automatic Switching Center (ASC) system description is presented to orient the reader.

A GPSS model of the Communications Data Processor (CDP) at the ASC was constructed, as a first step toward constructing an overall ASC simulation model. The capabilities and limitations of the simulation are discussed. Several experiments were conducted to ascertain the effects on the CDP message congestion and transit time of varying the volume of traffic passing through the system and the number of tributaries capable of receiving traffic.

A COBOL program, which calculates queuing information for the ASC tributaries, is described. The results of the program output are interpreted and uses of the information produced are discussed. Observed problem areas are presented.

Conclusions are drawn concerning the performance of the AUTODIN ASC as shown by the simulation and program. Anticipated project applications are described.

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TABLE OF ABBREVIATIONS

ADU	Accumulation and Distribution Unit
AFB	Air Force Base
ASC	Automatic Switching Center
AUTODIN	AUTOmatic DIgital Network
BBU	Bit Buffer Unit
BCU	Buffer Control Unit
BPU	Basic Processor Unit
CARP	Contingency Alt Route Plan
CDP	Communications Data Processor
COBOL	COmmon Business Oriented Language
CONUS	CONtinental United States
CSU	Circuit Switching Unit
DCS	Defense Communications System
FIFO	First In First Out
GPSS	General Purpose Simulation System
HSM	High Speed Memory
IC	InterCept tape
I/P	InPut
MID	Message Identification Number
MIR	Mean Input Rate
MMU	Mass Memory Unit
MNTP	Mean Number of Transactions In Process

MODEM	MOdulator/DEModulator
MST	Mean Service Time
MSU	Message Switching Unit
MTIP	Mean Time In Processing
O/P	OutPut
OVT	OVerflow Tape
PLT	Program Library Tape
RI	Routing Indicator
UTIL	facility UTILization
WPM	Words Per Minute

I. INTRODUCTION

A. PURPOSE

The purpose of this thesis is to examine the Automatic Digital Network (AUTODIN) and Automatic Switching Center (ASC), including its associated tributaries, and describe how a simulation model and tributary utilization program can be used by the AUTODIN manager to analyze various portions of the system. If the demands placed on the AUTODIN continue to increase, as is predicted, the ASC manager will require methods of ascertaining the extent of facility utilization and other measures of effectiveness for his portion of the network to help pinpoint potential problem areas, as well as, determine system effectiveness and efficiency. At the present time there is not available to the ASC manager all the proper tools or techniques necessary to make this determination.

This thesis presents a general network description to orient the reader, followed by a description of two management tools and their applicability to an analysis of the message switching portion of an ASC, its tributaries and the connection circuits and trunks.

The first tool, a computer simulation of the ASC Communications Data Processor (CDP), was developed as a part of this thesis using the General Purpose Simulation System (GPSS) language. This simulation is a first step toward providing an overall ASC simulation, which would be of considerable value to the ASC manager in testing potential configuration changes, variances in traffic loads and other changes which would be

impossible to test at this time due to the nonexistence of such a simulation model.

The second tool, a COBOL program, was developed by the author to determine the tributary utilization percentages and other queuing information for the tributaries of an ASC. Results of the program output are interpreted and uses of the type of information produced are discussed, and observed problem areas presented.

An analysis of the output of the program and simulation is presented to give some indication of the types of information which can be derived from the programs. Finally, conclusions are drawn concerning the use of the management tools at the ASC and potential future roles.

The ASC at McClellan AFB, California and tributaries associated therewith were chosen as an example on which to base the CDP simulation and analysis, in as much as it was the most accessible to the author and data on that particular installation were readily available. The tributary utilization program makes use of message traffic volumes from the ASCs at McClellan AFB and Norton AFB, California. However, the techniques, methods and computer programs developed here are equally applicable to other ASCs and tributaries provided that modifications are effected to accommodate variations peculiar to the installation being examined.

B. SCOPE

In the conception stages of this thesis it was envisioned that the

entire operating system of the message switching portion of the ASC would be simulated. However, several restrictive choices had to be made concerning the scope of the project as a whole as well as the nature of the simulation itself. As work and time progressed it became clear that only a small portion of the total ASC could be properly simulated in the time available, but that this would be an important first step toward an over-all ASC simulation model. Interest in furthering this work has been generated at the Naval Postgraduate School and hopefully the effort will continue. This restriction was not considered to be unreasonable in view of the generally accepted fact that the system analyst often finds it necessary to limit the area of study undertaken in order to attain his objective of a viable analysis.

II. BACKGROUND

A. GENERAL NETWORK DESCRIPTION

The Automatic Digital Network (AUTODIN) is a switched network, which along with the Automatic Voice Network (AUTOVON), constitute a major portion of the worldwide Defense Communications System (DCS). The AUTODIN processes 95 percent of the Department of Defense record traffic, which amounts to about one million messages a day. It currently costs about eighty million dollars a year to operate this system for over 1300 subscribers located throughout the world. The network consists of two systems. One, a system leased from Western Union, located in the continental United States (CONUS AUTODIN) and the other a system serving the overseas area, 60 percent of which is government owned and operated and 40 percent leased [Ref. 1].

The AUTODIN is made up of Automatic Switching Centers (ASC); ASC tributaries, which comprise the 1300 subscribers; and the interconnecting circuits, trunks and transmission links, and terminal facilities.

The AUTODIN was developed to provide a worldwide network capable of operating at required speed, security, accuracy and reliability levels for effective long haul point-to-point communications. Circuit speeds vary from 75 baud (100 WPM) to 4800 baud (6000 WPM) depending on configuration, with speeds of 9600 baud (12000 WPM) expected in the near future.

Message security is provided through the use of link encryption; each circuit with a requirement for passing classified information is secured by

cryptographic equipment. The ASC has the capability of detecting and preventing the transmission of classified information over unsecured circuits.

Accuracy is obtained through the use of error detection codes and correction functions. These methods ensure that each character of a message is accurately preserved from the time it is introduced into the network until it reaches its final destination. Automatic accuracy control facilities at both the ASC and tributary stations ensure that not more than one error in 10^6 characters processed goes undetected. ASCs are engineered to automatically correct detected errors or initiate an alarm to the operator identifying the error condition.

Reliability at the ASC and tributaries is attained through equipment redundancy. Each ASC has two computers for processing message traffic plus a variety of spare peripheral equipment available. The tributaries have varying degrees of redundancy depending on the individual terminal configuration. Reliability in the event of circuit and switch outage is ensured through the Contingency Alt Route Plan (CARP). This is a network-wide plan in which each subscriber has been consulted and provided an alternate route for his traffic. A tributary precedence and circuit restoration priority system is maintained to help preserve network integrity. The overall network currently provides a reliability of proper operation of greater than 99 percent.

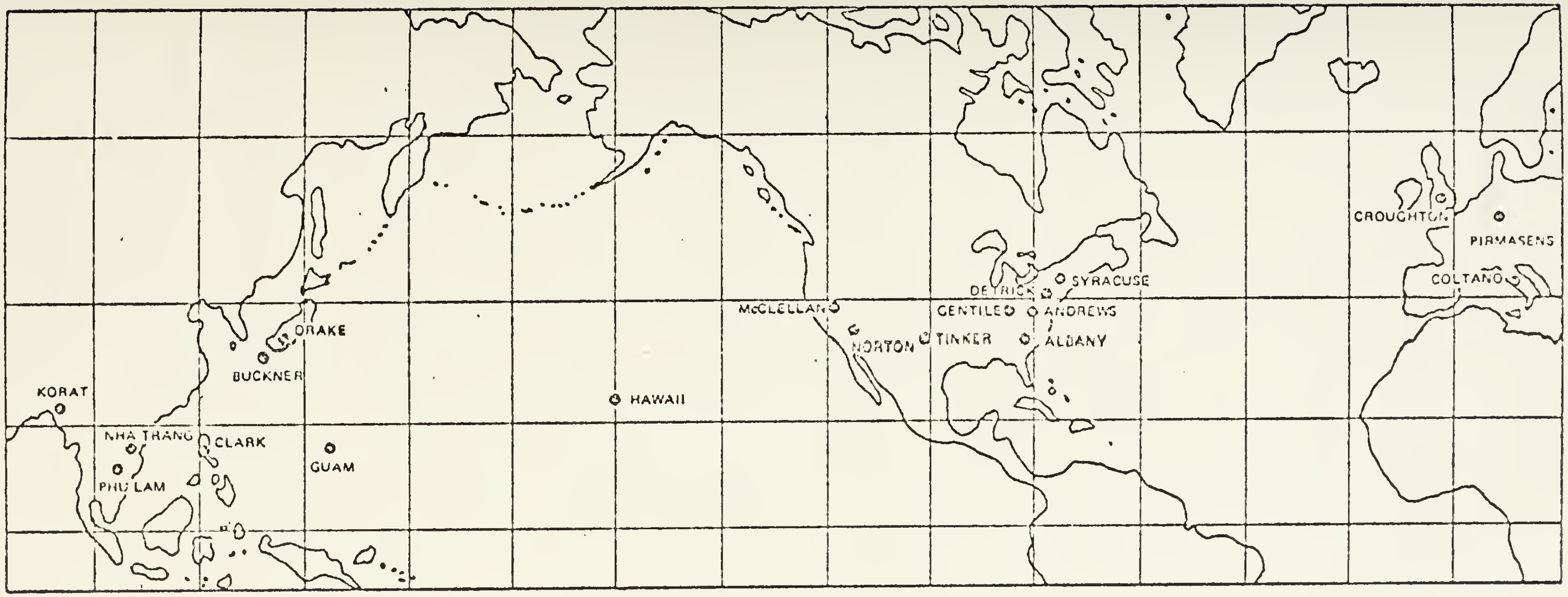
B. THE AUTOMATIC SWITCHING CENTER

1. ASC Functions

The ASCs are the interconnected message and circuit switching points of the AUTODIN, each originally designed to accommodate 250 message switching users and 50 circuit switching users. There are eight leased ASCs in CONUS and eleven government owned ASCs overseas. The geographic location of each ASC is shown in figure 1. The four major functions performed by the ASC are: circuit switching, message switching, message processing, and message bookkeeping and protection.

a. Circuit Switching

Normally, a terminal is designated a circuit switching user if it is one which has a large volume of traffic addressed to a select few addresses. In most cases these addressees are connected to a like circuit switching user terminal. A direct means of communicating between the terminals is established through the Circuit Switching Unit (CSU) of the ASCs. This portion of the ASC provides for the interconnection of terminals which have the same speed, language media format, and compatible equipment for the exchange of single addressed message traffic or data. In the event that a called terminal is busy, not compatible, or the message is multiple addressed, the CSU provides a connection with the message switching portion of the ASC through inter-change circuits, where necessary format, code, and speed conversion are carried out by the Communications Data Processor.



DCS AUTODIN
SWITCHING CENTERS

LOCATION	O & M RESPONSIBILITY	LOCATION	O & M RESPONSIBILITY
1. ALBANY MCSC, GA.	USN	11. CLARK AB. P.I.	USAF
2. ANDREWS, AFB, MD.	USAF	12. CP DRAKE, JAPAN	USAF
3. FT. DETRICK, MD.	USA	13. NAVCOMSTA FINEGAYAN, GUAM	USN
4. GENTILE AFS, OHIO	USAF	14. NAVCOMSTA WAHIAWA, HAWAII	USN
5. McCLELLAN AFB, CALIF.	USAF	15. KORAT RTAFB, THAILAND	USAF
6. NORTON AFB, CALIF.	USAF	16. NHA TRANG, REP OF VIETNAM	USA
7. HANCOCK FIELD, N.Y.	USN	17. SAIGON, REP OF VIETNAM	USA,
8. TINKER AFB, OKLA.	USAF	18. CROUGHTON RAF STATION, ENGLAND	USAF
	USAF	19. COLTANO SITE, LEGHORN, ITALY	USA
10. FT. BUCKNER, OKINAWA, RYIS	USA	20. PIRMASENS, GERMANY	USA

Figure 1. Geographic Locations of ASCs.

In actual practice it was found that although circuit switching provides real-time response between users, it had a very low utilization. Currently the ASC at Tinker AFB is the only one providing circuit switching within CONUS and all circuit switching users are serviced through this ASC.

b. Message Switching

The message switching function involves taking the message from the various incoming channels of the ASC, converting the code and speed as necessary to conform with the intended outgoing channel, and delivering the message to the proper outgoing channel. The messages transmitted by the system conform to certain specified formats, all being composed of a header, text, and ending. The message header contains information about the message such as its source, destination, security classification, precedence, and type. The text contains the actual information being sent, and the message ending serves to identify the ending point of the message. The message switching operates under the direction of information contained in the header and ending. No change to the text is carried out. The routing of messages through the various channels to its proper destination is accomplished in the AUTODIN by examining the message header and interpreting special groups of characters called Routing Indicators (RI). Every network subscriber is not assigned a unique channel at an ASC. There are many subscribers who are served by using some form of multiple subscriber facility, e.g. minor relay center, message delivery center. Network traffic flow is

controlled by RIs, which are not necessarily assigned to every subscriber, but do describe uniquely an organization or delivery point. The types of routing service available include single routing, collective routing, and multiple routing.

Message switching employs the store-and-forward concept of transmission, in which each message is accumulated in its entirety at each ASC on its route then routed and retransmitted as outgoing channels become available. Selection of messages for retransmission over available outgoing channels is made on a first-in-first-out (FIFO) basis according to message precedence. Levels of precedence, five of which are recognized by the system, are assigned by the originator of the message and not changed by the system. The system is designed so that receipt of Flash Override, Flash, and Immediate precedence messages will cause an interrupt of a lower precedence message being sent over the channel required by the high precedence traffic.

c. Message Processing

Functions associated with message processing include: routing line segregation, security checking, accuracy checking, storage, history records, priority handling and statistics.

d. Message Bookkeeping and Protection

The major tasks which fall in the category of bookkeeping concern the records, tables and logs concerning linking, storage and status of received traffic in order to keep accurate track thereof. The requirement of message protection dictates that once a message has been

successfully received by an ASC, it is the responsibility of the system to deliver the message to all designated receivers. Message protection is implemented by both programming and hardware features. These provide a series of check-points throughout the system, where the messages are still held after transmission to the next check-point, until its successful receipt is acknowledged, making possible corrective action or reconstruction of the desired message.

2. ASC Major Equipment

The major functions of the ASC are accomplished by utilizing several special purpose computers, related peripheral devices and necessary communications equipment. A block diagram of the major components of an ASC operating system is provided in figure 2, which will be a helpful reference in the following discussion of these pieces of equipment and their operation. The technical information essential to the following equipment and operation description was acquired from the many Air Force, DCA, and privately published works on the subject [Refs. 2-11].

a. Technical Control Facilities

The Technical Control facilities, which are used for terminating communication lines and for interconnecting links between communication lines and the message switching unit (MSU) and/or the circuit switching unit (CSU), include the modulating-demodulating (MODEM) equipment, monitoring and measuring instruments, cryptographic devices, and switching facilities.

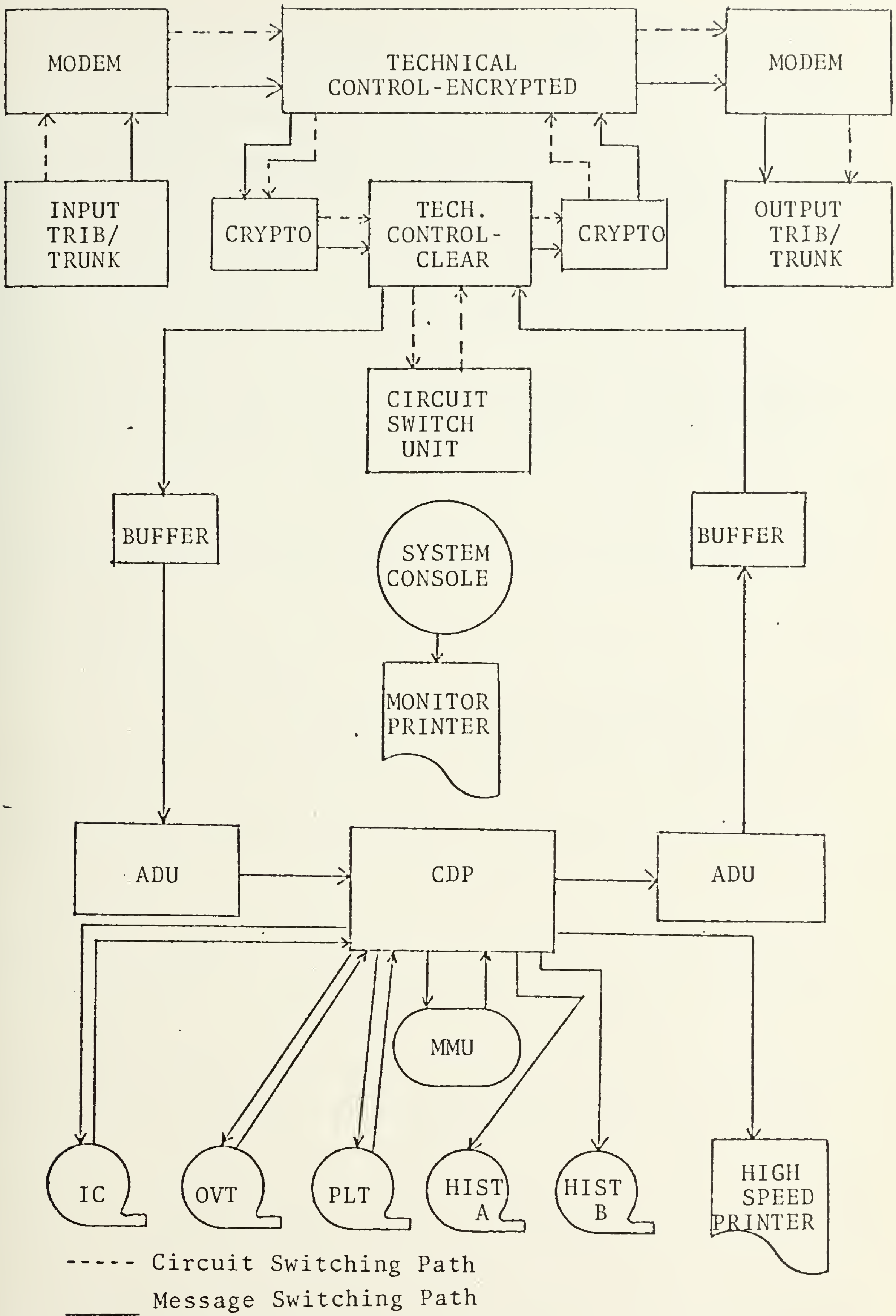


Figure 2. ASC Major Components.

The message traffic arrives at the ASC over the incoming channel lines from the ASC tributaries or interconnecting trunks. The message transmission along these circuits is in a carrier form up to the MODEM and a low level D. C. signal thereafter. The MODEMs are also used to convert this analog signal used for transmission in the voice frequency band back to digital signals for ASC internal processing. The purpose of monitoring and measuring instruments is to indicate communications line continuity and signal quality. The cryptographic devices provide communication channel traffic security protection, and the switching facilities connect buffering equipment to the corresponding communication channels.

b. Buffer System

The Buffer System links the Technical Control facility with the Accumulation and Distribution Units (ADU), provides temporary storage for speed matching and contains the controls necessary to interface the ADU with the communications channels. A Buffer System consists of two Bit Buffer Units (BBU) and three Buffer Control Units (BCU). The BBU terminates up to 128 full duplex bit-serial communication lines coming from and going to Technical Control, and provides a common interface to the BCU. The BCU interfaces the BBUs and the ADUs, using a magnetic core memory to store individual communication line conditions. In addition, the BCU performs character conversion from serial-by-bit to parallel-by-bit and serial-by-character.

c. Accumulation And Distribution Unit

The Accumulation and Distribution Unit (ADU) is a special purpose computer operating with combined wired-in and stored programs. Its purpose is to provide the necessary controls and storage for data both being received from and transferred to the communication channels, via the buffers. Each ASC has three separate ADUs, with two being on-line and one in standby. Each ADU can accommodate up to 125 incoming/outgoing channels. The ADU holds the messages destined for the CDP in one of three ADU zones, which are the terminus of the input transfer channels and the starting point for outgoing transfer channels. These zones have been labeled as High, Medium and Low Speed Zones. Their characteristics will be described later. The ADU transfers messages from and to the CDP at the rate of 1240 lineblocks per second. The ADU translates recevied message characters into Fieldata code for use in the CDP; assigns the Message Identification Number (MID); makes the lineblock parity checks and stores the lineblocks in the core memory until the complete message is forwarded to the CDP. For outgoing messages, the ADU translates the message from Fieldata to an appropriate code to match the recipient's equipment, and passes the message to the line termination buffer, where it passes out of the ASC.

d. Communications Data Processor

The Communications Data Processor (CDP) is a large scale digital computer, usually an RCA 9602 or third generation RCA Spectra 70, designed especially to perform and control communications switching

functions. The CDP controls the flow of data through the ASC and processes the data according to the AUTODIN program and commands from the system console. The CDP receives the message from the ADU one lineblock at a time. The CDP, upon receipt of the first lineblock, validates the message header and determines proper routing for the message. The lineblocks are then accumulated in memory one lineblock at a time, with an acknowledgement returned after each, until the end of the message is received. Acknowledgement of message receipt is then transmitted to the sender. The message is then linked in the appropriate address queue to await channel assignment and movement on a FIFO basis, subject to message precedence and line availability. There are two CDPs at each ASC with one on-line and the other in standby or utilized for off-line work. The CDP is made up of a Basic Processor Unit (BPU), a High-Speed Memory (HSM), a Processor Operators Console, and a series of Transfer Channels which interface various peripheral devices with the BPU. Two of the most outstanding features of the CDP are its simultaneity and interrupt features. The CDP has the ability to operate several of the peripheral devices asynchronously with internal processing. At the termination of each peripheral device operation, the current CDP program is automatically interrupted, and all register settings are stored. The interrupt feature enables return to this point in the program at a later time without loss of continuity. These features allow the system to initiate peripheral device operation and continue with other tasks with a resulting reduction in message transit times and increase in computer through-put.

e. Peripheral Devices

The more important peripheral devices are shown in figure 2 and include: (1) the In-Transit Storage (MMU), (2) Magnetic Tape Stations, and (3) High Speed Printers. The In-Transit Storage (MMU) is the temporary storage area where messages received at the ASC reside until complete retransmission out of the ASC. The MMU consists of disc or drum storage units.

There are eighteen Magnetic Tape Stations in the system. The Program Library Tape (PLT) contains the AUTODIN software program. Two tape stations, identified as History A and B, record historic data and message contents. The Intercept Tape (IC) is used to hold traffic which cannot be delivered to its destination. The Overflow Tape (OVT) is used to hold messages when "overload" conditions exist, i.e., when the MMU capacity has been exhausted.

The High Speed Printer is located at the CDP Console and the Monitor Printer at the System Console, enabling the operator to access the system as required. The System Console is where the entire operation of the ASC is monitored and alarms are actuated to indicate problems.

3. ASC Tributaries

Each ASC provides the AUTODIN end point/entry point service to commands and activities located in roughly the same geographic area as the ASC. The physical setup is referred to as a tributary, which consists of the terminal equipment and transmission line interconnecting the ASC and the command or activity message center.

There are a variety of tributary configurations available to meet the needs of the individual subscriber. Terminals are classified by the form in which traffic is exchanged with the ASC. There are four basic types: (1) Teletype Terminal; (2) Compound Terminal, capable of handling both teletype and Hollerith cards; (3) Magnetic Tape Terminal; and (4) Computer Terminal. Tributaries also vary depending upon their particular Channel Mode. There are five different operational channel modes used in the AUTODIN (Mode I through Mode V). The Mode I and Mode V are by far the most frequently used and are described as follows:

The Mode I is capable of full duplex operation with automatic error detection and channel controls allowing independent and simultaneous two-way operation at 45, 75, 150, 300, 600, 1200, 2400, or 4800 baud. Terminals using this mode are compound, magnetic tape, and computer.

The Mode V is capable of full duplex operation associated with teletype equipment at 75 baud only and allowing independent and simultaneous two-way transmission with partial control.

4. AUTODIN Transmission Lines

The AUTODIN makes use of a variety of transmission media to interconnect the ASCs and tributaries which comprise the nodal and terminal portions of the network. These media include: (1) high frequency radio; (2) microwave; (3) tropospheric scatter; (4) satellite; plus (5) several kinds of landline cables and wires. Practically all of the CONUS AUTODIN transmission lines are leased from commercial communications companies such as the Bell Telephone Company.

Two different types of circuits within the AUTODIN can be defined by the function they perform: (1) Interswitch Trunks and (2) Tributary Circuits. Interswitch trunks are high speed, normally 1200, 2400, or 4800 baud circuits connecting the ASCs. These are the backbone of the long haul point-to-point portion of the AUTODIN. Each ASC does not have a dedicated trunk to every other ASC, but will have trunks to the closest six or seven ASCs with a relay capability through these to the remainder of the network. Tirbutary circuits are the full duplex dedicated circuits which connect the tributary with the ASC. These tributaries can be activated on a full time basis or only part of the time and vary in speed capability depending upon the configuration of the tributary being served.

IV. CDP SIMULATION MODEL

A. NATURE OF THE PROBLEM

"One of the most powerful tools that can be used in estimating the requirements of a system is simulation" [Ref. 12]. In the AUTODIN an overall network simulation has been constructed for DCA by the Computer Sciences Corporation [Ref. 13]. It is a mammoth FORTRAN program requiring large amounts of core storage and numerous peripheral devices such as magnetic tape units and disc drives. It can therefore only be run on a large computer. In spite of its complexity, this network-wide program treats the ASC in no more detail than the use of a time delay for processing and traffic load as generated by history tapes for that ASC [Ref. 14]. This may well suffice for an overall network analysis of traffic flows, circuit and switch loading, but it does not yield much useful information on the inner workings of the ASC.

Simulation is particularly well suited for analyzing complex operations. Simulation can be valuable in obtaining a picture of what is happening when there is a high degree of multiprogramming and processing; or even in determining whether a high level of multiprogramming is in fact necessary. However, GPSS, the language used in this simulation does not lend itself particularly well to the incorporation of multiprogramming features. A simulation can indicate the waiting times and queue lengths at various traffic loads and for various tributary conditions and configurations. It can provide insights into system configuration improvements to better serve the ASC, tributary and network as a whole.

An ASC simulation should be a valuable tool to assist the ASC manager in better understanding his system and what it can and cannot do. The simulation model would also be helpful for use in planning ASC operations and for personnel training.

B. EXPERIMENTAL PROCEDURE

1. CDP Components And Processing Steps

As indicated in the background portion of this thesis, the Communications Data Processor (CDP) is a large scale digital computer which controls the overall operation of the ASC, performs message switching, and numerous other checking and bookkeeping tasks associated with the AUTODIN. A more detailed description of the components and processing steps involved in the CDP simulation model and their relationship is considered essential, in this section, in order to establish an underpinning for the subsequent model presentation and analysis. See figure 3.

The CDP contols the overall operation of the message switching function of the ASC. This includes the scheduling and execution of processing functions performed within the High Speed Memory (HSM) as well as controlling the operation of the associated peripheral devices and transfer channels.

Messages are transferred from the three ADU zones via the ADU/CDP transfer channel into the HSM of the CDP. Input Processing of the message is performed, which includes interpretation of the destination from the Routing Indicators contained in the heading, acknowledgement

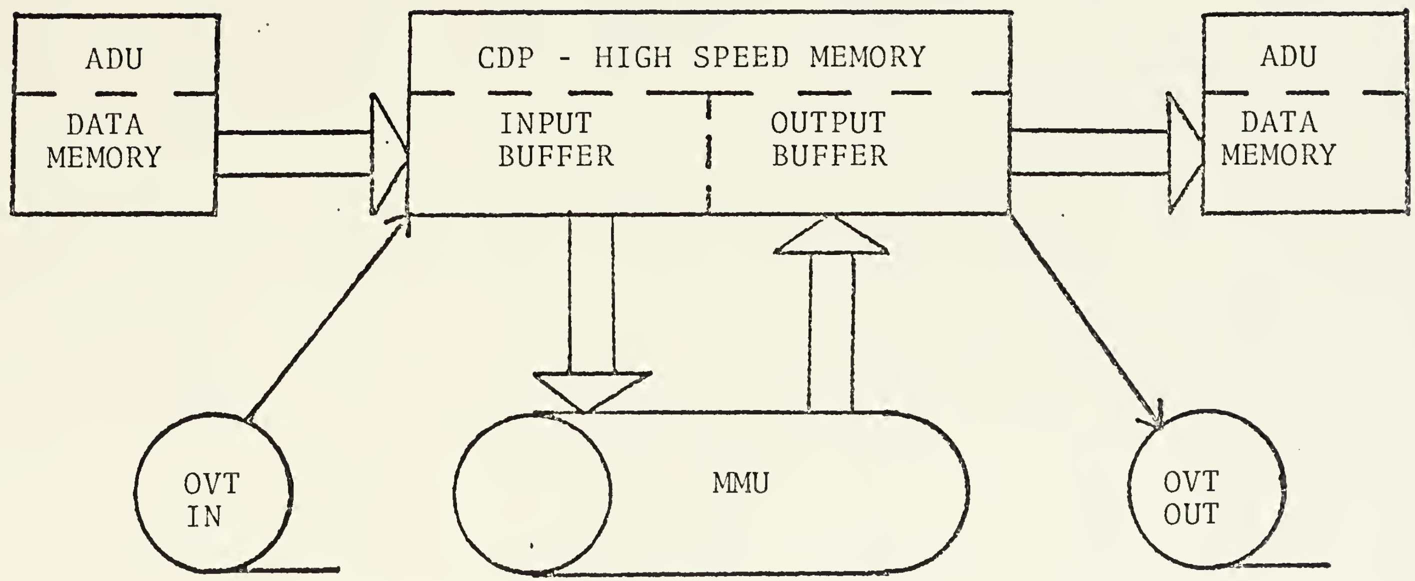


Figure 3. Message Data Flow Through The CDP.

of receipt of the message to the sending ASC or tributary plus other administrative functions. Upon completion of Input Processing, the message is transferred to Intransit Storage on the MMU via the CDP/MMU transfer channel. Upon availability of the proper channel for the outgoing message, the message is transferred to the HSM again for Output Processing via the MMU/CDP transfer channel. Upon completion of Output Processing, the message is transferred out of the CDP to the appropriate ADU zone via the CDP/ADU transfer channel.

Several peripheral tape units are utilized for storage of message traffic in the event of overloading of the MMU or for collection of traffic destined for a specific tributary which is unable to receive traffic due to equipment failure or because of being a part-time subscriber.

2. Characteristics Of The Simulation Model

The characteristics of the CDP are treated in this simulation model from the functional point of view. This reduced the level of detail to within manageable limits and, in fact, made the simulation effort feasible. The individual instructions are not simulated but only the times and characteristics of the various functions included. Certain restrictions on the simulation program were necessary. If the simulation was formulated to the level of detail of individual instructions in the CDP, the simulation would run many times slower than the actual instruction execution time [Ref. 15]. Even with this simplification, one day of real time required more than thirty minutes of computer time to execute.

In addition, as was pointed out in the background section, one of the important features of the CDP is its simultaneity of operation and multiprogramming ability. The result of this is that messages are not actually handled serially through the system, but rather, many operations occur simultaneously on different messages throughout the system. The approach taken in the simulation is again a departure from the way things actually happen in the system. Messages are generated and flow serially through the steps of the simulation, with statistics gathered on such items as queues, transit times, storage and facility utilizations, and message sizes. A factor derived from actual system through-put was computed to measure the degree of simultaneity which is present in the CDP. This factor is the ratio of throughput using multiprogramming to throughput using monoprogramming. The simulation times were modified by this factor so that the model does in fact approximately reflect simultaneity of operation. The simultaneity feature of the CDP was incorporated so that mean service times computed by the simulation would be accurate representations of those actually experienced by the ASC.

As mentioned previously, the logic of this simulation takes a message serially through the processing steps and equipments that would be experienced in the message switching portion of the CDP while performing normal store-and-forward functions on record message traffic. A detailed description of the simulation model that was developed as a part of this research is contained in Appendix A and a Block Diagram is provided in Appendix B.

In the simulation, messages are generated at the rate of .35 messages per second, which was the actual mean arrival rate of messages at the ASC McClellan, calculated over a four month period. In the absence of specific information on the distribution of inter-arrival times, an exponential distribution was assumed.

The mean message length, determined by the same means as for the inter-arrival times, was 33 lineblocks. An exponential distribution of message length was assumed. Messages vary in length but a lineblock is standardized at 80 information carrying characters plus four framing characters. Each character is eight binary digits (bits) in length.

The characteristics of the actual CDP and values assigned are summarized below:

a. The transfer channel between ADU and CDP has a transfer rate of 1240 lineblocks per second.

b. Input processing consists of a mean of 20 thousand computer instructions, exponentially distributed; with from 1 to 77 cycles per instruction, uniformly distributed; and from 1.2 to 2 microseconds of execution time per cycle, uniformly distributed. Input processing is carried out in the HSM which has a capacity of 6461 lineblocks.

c. The transfer channel between HSM and MMU has a transfer rate of 4166 lineblocks per second.

d. The MMU has a capacity of 112896 lineblocks, of which 75% is allocated to intransit storage. When 80% of the space allocated to intransit storage is filled, emergency procedures are initiated and low

precedence traffic is diverted to overflow tapes. Therefore, the actual capacity of intransit storage under normal conditions is 64512 lineblocks.

Three user chains were constructed in the MMU to correspond with the three ADU zones. (See Appendix A, page 62, for an explanation of user chains.) Time delays in each chain and the amount of traffic which occupied each chain was determined by actual percentage of traffic which was handled by each tributary in that zone. The three ADU zones are labeled High, Medium, and Low Speed zones. The High Speed zone has a capacity of 28 lineblocks and is the terminus of all 4800 and 2400 baud circuits and trunks. A total of 74.3% of the traffic handled by the ASC occurs on these lines. The Medium Speed zone has a capacity of 18 lineblocks and is the terminus of all 1200 and 600 baud circuits. A total of 18.6% of the traffic occurs on these lines. The Low Speed zone has a capacity of 6 lineblocks and is the terminus of all 300, 150, 75, and 45 baud lines. A total of 7.1% of the traffic occurs on these circuits.

e. Output processing consists of a mean of 10 thousand computer instructions with the same characteristics as for Input Processing.

C. INTERPRETATION OF RESULTS

The purpose of interpreting the results of this simulation is more to show what results are available and what can be done with these results rather than to conduct a comprehensive analysis of the CDP operation. This interpretation will be structured so that a description of the more important component or process performance measurement criteria of the

simulation is followed by an observation of the values and times for these measurement criteria under normal traffic loads and network conditions. The effect on these values, brought about by modifying the simulation to reflect such occurrences as doubling the traffic load or rendering inoperable certain of the high, medium or low speed tributaries, is then indicated. A tabular form was selected as the method for presenting the values and modifications.

1. Definition of Performance Measurement Criteria

In interpreting the results of the simulation, it is necessary to identify the performance measurement criteria which are applicable. A block diagram of the simulation components and processing steps, as they relate to the model, is provided in figure 4. The GPSS element, e.g. facility, queue, or storage, number is included to assist in correlating the diagram with the simulation model description in Appendix A, block diagram in Appendix B, and simulation model output in the Computer Output section on page 74.

The performance measurement criteria, applicable to various items in figures 6 through 10, are defined below, in order of their appearance in the figures. The actual values for the various items are tabulated in the figures, with analysis and interpretation in accompanying paragraphs.

The measurement criteria contained in figure 6, for each run, consist of the following:

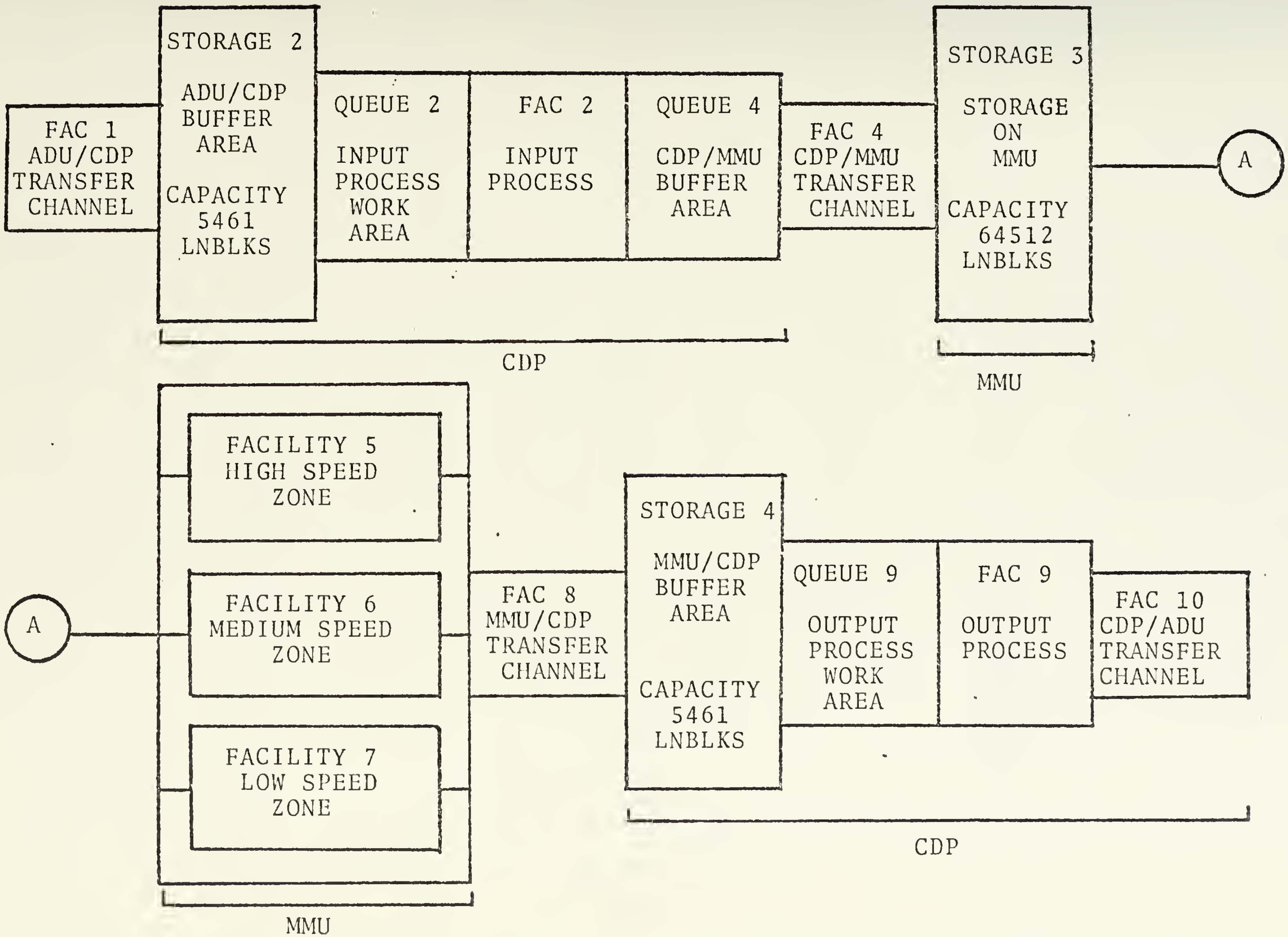


Figure 4. Simulation Model Components And Processing Steps.

a. Mean Message Service Time is the mean argument of Table 1 in the simulation output, Computer Output Section, page 75. The value found in figure 6, Column 2, represents the actual time, in seconds, required for a message to pass through all of the processing steps of the ASC CDP. It does not include wait times.

b. Mean Input (I/P) Processing Time is the AVERAGE TIME/TRAN of Facility 2 in the simulation output. The value found in figure 6, Column 3, represents the average amount of time, in seconds, required for a message to complete input processing. The same value, in milliseconds, is found in figures 8 through 10 for I/P Processing.

c. Mean Output (O/P) Processing Time is the AVERAGE TIME/TRAN of Facility 9 in the simulation output. The value found in figure 6, Column 4, represents the average amount of time, in seconds, required for a message to complete output processing. The same value, in milliseconds, is found in figures 8 through 10 for O/P Processing.

d. Input (I/P) Utilization is the percentage of time the Input Processing facility (Facility 2) was utilized during the course of the simulation run. The same value is tabulated in figures 8 through 10 for I/P Processing in the UTIL column.

e. Output (O/P) Utilization is the percentage of time the Output Processing facility (Facility 9) was utilized during the course of the simulation run. This value is tabulated in figures 8 through 10 for O/P Processing in the UTIL column.

The measurement criteria for the MMU tabulated in figure 7 for each run consists of the following:

a. The Average Time, in seconds, that a message spent in the MMU.

b. The Maximum contents of the MMU, in lineblocks, during the course of the simulation run.

c. The Average Time, in seconds, that messages spent in the High, Medium, and Low Speed zones while awaiting a call back to the CDP for Output Processing upon availability of an outgoing channel. Related to these zones is the next measurement criteria, the percent utilization of these zones during the course of the simulation run.

The measurement criteria for figures 8 through 10 consist of the following:

a. The Mean Wait Time (Column 1), in milliseconds, is the amount of time a message had to wait before proceeding on to the next point in the CDP. This mean included the occurrences of zero wait times.

b. Column 2 is a tabulation of mean wait time, in milliseconds, excluding all zero wait times from computation of the mean value.

c. Mean Processing Time (Column 3) is the amount of time, in milliseconds, spent in processing at the various processing facilities in the CDP and peripheral devices.

d. The percent Utilization (UTIL) (Column 4), described previously for figures 6 and 7, is the percent of time the CDP components and processes were utilized in the course of the simulation run.

e. Columns 5 and 6 tabulate the Mean Queue Size and Maximum Queue Size, in lineblocks, for applicable components and processes.

2. Simulation Model Analysis

As can be seen from a brief survey of the numerical values contained in the simulation printout, in the Computer Output section, page 74, the most important information can be derived from the Facility Utilization and Average Time Per Transaction, Storage Contents and Average Time Per Transaction, Queue Contents, plus the Mean Argument and Distribution of values for each of the five tables. The identification of the components and processes that the various facility, storage, queue, and table numbers represent, is presented in the tables located in Appendix A.

Figure 5 describes the characteristics of each simulation run and the run numbers which are assigned in this figure are used in the tables following to indicate the values for each run.

RUN NUMBER	RUN DESCRIPTION
1	One hour run, set up for normal message volumes and all tributaries operative.
2	One hour run, set up for double the normal message volumes; one medium speed tributary inoperative.
3	One hour run, set up for normal message volumes; one medium and three low speed tributaries inoperative.
4	One hour run, set up for normal message volumes; one medium speed tributary inoperative.
5	One day run, set up for normal message volumes and all tributaries operative.

RUN NUMBER	RUN DESCRIPTION
6	One day run, set up for normal message volumes; one medium and three low speed tributaries inoperative.
7	One day run, set up for double message volumes and one medium speed tributary inoperative.
8	One day run, set up for double message volumes; one medium and three low speed tributaries inoperative.

Figure 5. Simulation Run Characteristics.

A tabulation of values for each of the components for the various runs described above is contained in figures 6 and 7, with measurement criteria defined in the previous section. A more detailed examination of the measurement criteria of each component and process for runs 5, 6, and 8 was conducted and the values tabulated in figures 8, 9, and 10.

An examination of the values in figure 6 reveals that the Message Service Times in the CDP, for all eight simulation runs, were very close, with a mean value of 2.86 seconds. This value corresponds to the actual estimated value of from several milliseconds up to three or four seconds. From this figure it can be ascertained that the sum of the time spent in the processing steps through the simulation yields a reasonable processing time.

The Input (I/P) Utilization (UTIL) was the item that was affected most by increases in message volume. From a mean utilization of 4.8 percent for normal volumes of traffic, the figure jumped to a mean of 9.7 percent when double the normal volume was generated. Even at that, less

than ten percent utilization was experienced with double the present traffic loads. This gives a strong indication that the ASC has more than sufficient capacity built into its equipment configuration. The same can be said for the Output (O/P) Utilization (UTIL), which experienced similar variations.

RUN	MEAN MSG SERVICE TIME (SECONDS)	MEAN I/P PROCESS TIME (SECONDS)	MEAN O/P PROCESS TIME (SECONDS)	I/P UTIL (%)	O/P UTIL (%)
1	2.94	.130	.065	4.8	2.2
2	2.80	.131	.064	9.8	4.8
3	2.83	.136	.064	5.0	2.3
4	2.91	.129	.066	4.6	2.4
5	2.85	.136	.060	4.7	2.3
6	2.85	.137	.065	4.8	2.3
7	2.84	.137	.066	9.5	4.5
8	2.83	.136	.066	9.6	4.6

Figure 6. CDP Processing Times and Utilization Percents.

Figure 7 is a tabular presentation of the measurement criteria related specifically to the MMU for all eight simulation runs.

As can be seen, the value for normal traffic volumes (runs 1 and 5) is approximately .1 seconds. However, as the message input volumes and number of tributaries operative were varied the times fluctuated in

response to the changes. The most serious backlogs occurred for runs 7 and 8, with 91.1 and 82.5 second wait times. This indicates that as message volumes increase and the ability of tributaries to receive fluctuate, the pressure is exerted on the MMU storage. This observation is further supported by the build up of lineblocks being stored at the MMU during the simulation as presented in the Maximum MMU Contents (Column 2). A maximum of a 359 lineblock build up occurred for run 5, whereas the maximum reached a high of 4200 lineblocks for run 8. When comparing this build up with the average time spent in the High, Medium, and Low Speed Zones (Column 3, 4, and 5) and utilization (Column 6, 7, and 8) for the corresponding runs, the trend disappears indicating that wait times for outgoing channels is relatively insensitive to message input volume and tributary availability.

The mean transit time is determined by summing the mean wait time and the mean service time. The mean service time is tabulated in column 1, figure 6. System wait time is the sum of all wait times through the system, but is dominated by the wait time in MMU storage, column 1, figure 7. Thus, a good indication of mean transit time for various runs can be determined by summing these two times.

The following analysis pertains to the more detailed examination of the measurement criteria, as tabulated in figures 8 through 10. As can readily be seen, as the volume of traffic increased from one run to the next, and the tributary operability status fluctuated, the mean wait times increased, while the mean processing time remained relatively stable.

The more detailed examination supported the trends and findings observed for the overall runs, but did provide the additional detail which would be desirable in an in-depth analysis of the network.

	MMU Storage		MMU Retrieval					
RUN	AVERAGE TIME/TRANS (SECONDS)	MAX MMU CONTENTS (LNBLKS)	AVERAGE TIME/TRANS (SECONDS)			UTILIZATION (%)		
			HISPD	MEDSPD	LOSPD	HISPD	MED	LOW
1	.143	300	.031	.117	.307	.7	1.0	.2
2	1.618	425	.031	.100	.152	1.5	1.6	.1
3	2.818	329	.032	.089	.166	.8	.7	0
4	1.042	276	.032	.088	.180	.8	.7	0
5	.106	359	.032	.099	.206	.8	.8	.1
6	64.89	1884	.032	.097	.187	.8	.7	.1
7	91.17	4037	.033	.096	.198	1.7	1.5	.2
8	82.54	4200	.032	.098	.199	1.6	1.6	.2

Figure 7. MMU Data and Measurement Criteria

From figures 6 through 10, it is evident that the present utilization of the CDP is very low. Even a doubling of message volume only increased the utilization of the most critical facility in the simulation (Input Processing) from 4.8% to 9.8% as would be expected. Thus the CDP is more than adequate to handle even a drastic rise in message

volumes. However, as can be seen in figure 7, run 6, the number of lineblocks being accumulated in the MMU as a result of one medium speed and three low speed tributaries being unable to receive their traffic for one day amounted to 1884 lineblocks and even more for runs 7 and 8. This provides an indication of where the potential problems lie within the AUTODIN: the tributaries. This will be developed more fully in the tributary utilization program and the conclusions sections.

D. PROBLEMS ENCOUNTERED

In researching the AUTODIN prior to initiating the simulation, one of the most difficult tasks was the identification of the equipment and system parameters and characteristics. Reasonable estimates were obtained from the competent ASC personnel but more detailed information must be obtained concerning AUTODIN operation and this information must be incorporated in the model to achieve increased accuracy.

Time did not so permit in this thesis, but the simulation should be carefully validated against actual performance data, when such exists. Appropriate CDP component and processing step performance criteria must be developed so that different simulation runs may be compared. In this thesis, only rough comparisons of generally accepted performance characteristics were effected. Very limited comparison of runs were carried out, e.g., using the model to show the difference in system performance figures when inter-arrival times of messages at the ASC, and the ability of the tributary to receive traffic are varied.

COMPONENT/PROCESS	MEAN WAIT TIME (MILLISEC)	MEAN WAIT TIME(NO 0) (MILLISEC)	MEAN PROCESS TIME (MILLISEC)	UTIL (%)	MEAN QUEUE SIZE (LNBLKS)	MAX QUEUE SIZE
ADU TO CDP TRANSFER CHANNEL	-	-	1.9	0	-	-
ADU TO CDP BUFFER	5.5	-	-	0	1.7	409
I/P WORK AREA QUEUE	8.8	199.3	-	-	.003	3
I/P PROCESSING	-	-	136.7	4.7	-	-
CDP TO MMU BUFFER	0	1.0	-	-	0	1
CDP TO MMU TRANSFER CHANNEL	-	-	.3	0	-	-
STORAGE ON MMU	54.7	-	-	0	1.2	359
RETRIEVE FROM MMU	-	-	51.3	.008	-	-
MMU TO CDP TRANSFER CHANNEL	-	-	.3	0	-	-
MMU TO CDP BUFFER AREA	0	-	-	0	.8	276
O/P WORK AREA	2.6	106.6	-	-	0	2
O/P PROCESSING	-	-	66.6	2.3	-	-
CDP TO ADU TRANSFER CHANNEL	-	-	1.9	0	-	-
TOTAL SUM OF MEAN WAIT TIME AND MEAN PROCESSING TIME	330.6					

Figure 8. Table of Simulation Performance Measurement Values (Run #5).

COMPONENTS/PROCESS	MEAN WAIT TIME (MILLISEC)	MEAN WAIT TIME(NO 0) (MILLISEC)	MEAN PRO-CESS TIME (MILLISEC)	UTIL (%)	MEAN Q SIZE (LNBK)	MAX Q SIZE (LNBK)
ADU TO CDP TRANSFER CHANNEL	-	-	1.9	0	-	-
ADU TO CDP BUFFER	7.1	-	-	0	1.8	331
I/P WORK AREA QUEUE	9.9	208.0	-	-	.003	4
I/P PROCESSING	-	-	138.3	4.8	-	-
CDP TO MMU BUFFER	0	1.0	-	-	0	1
CDP TO MMU TRANSFER CHANNEL	-	-	.3	0	-	-
STORAGE ON MMU	64838.7	-	-	1.1	737.7	1884
RETRIEVE FROM MMU	-	-	50.73	.007	-	-
MMU TO CDP TRANSFER CHANNEL	-	-	.3	0	-	-
MMU TO CDP BUFFER AREA	0	-	-	0	.8	276
O/P WORK AREA	2.7	96.7	-	-	0	3
O/P PROCESSING	-	-	66.5	2.3	-	-
CDP TO ADU TRANSFER CHANNEL	-	-	1.9	0	-	-
TOTAL SUM OF MEAN WAIT TIME AND MEAN PROCESSING TIME	65118.3					

Figure 9. Table of Simulation Performance Measurement Values (Run #6).

COMPONENTS/PROCESS	MEAN WAIT TIME (MILLISEC)	MEAN WAIT TIME(NO 0) (MILLISEC)	MEAN PROCESS TIME (MILLISEC)	UTIL (%)	MEAN Q SIZE (LNBK)	MAX Q SIZE (LNBK)
ADU TO CDP TRANSFER CHANNEL	-	-	1.9	.1	-	-
ADU TO CDP BUFFER	4.4	-	-	0	3.7	453
I/P WORK AREA QUEUE	19.9	208.6	-	-	.013	4
I/P PROCESSING	-	-	137.7	9.6	-	-
CDP TO MMU BUFFER	0	1.1	-	-	0	1
CDP TO MMU TRANSFER CHANNEL	-	-	.3	0	-	-
STORAGE ON MMU	82493.8	-	-	2.9	1882.4	4200
RETRIEVE FROM MMU	-	-	51.12	.016	-	-
MMU TO CDP TRANSFER CHANNEL	-	-	.3	0	-	-
MMU TO CDP BUFFER AREA	0	-	-	0	1.6	348
O/P WORK AREA	5.6	107.4	-	-	.003	5
O/P PROCESSING	-	-	66.4	4.6	-	-
CDP TO ADU TRANSFER CHANNEL	-	-	1.9	.1	-	-
TOTAL SUM OF MEAN WAIT TIME AND MEAN PROCESSING TIME	82783.3					

Figure 10. Table of Simulation Performance Measurement Values (Run #8).

III. TRIBUTARY UTILIZATION PROGRAM

A. NATURE OF THE PROBLEM

Particularly widespread throughout the military communications business is the tendency to install a communications capability based on the needs at the time without ever again reviewing the installation to determine if the requirements have changed as mission and functions of the activity being served change with time. Through the author's observation of present procedures it is quite possible that communications capabilities and circuits vital during the Korean War or the Cuban Missile Crisis, but which have long since fallen into disuse, are still being funded and maintained.

On the other hand, on several occasions in the past, the volume of message traffic at an ASC, awaiting delivery to its tributaries, has reached such a level that the computer operating system was required to initiate emergency procedures to alleviate the system overload which resulted. The suspected cause of the large backlogs of traffic is that certain ASC tributaries are not capable of adequately handling traffic volumes due to terminal limitations [Ref. 16].

The primary objective of this portion of the thesis is to discuss the development of a technique for ascertaining and analyzing the utilization of the existing ASC tributaries. It is envisioned that this technique could also be utilized in the early stages of the design or modification effort on the tributary configuration. The approach taken was to develop a queuing

analysis of all the ASC tributaries associated with the ASC at McClellan AFB and Norton AFB.

By employing queuing analysis, it is possible to calculate the approximate mean queue size, and the mean message wait time. The probability of queues exceeding certain values can also be estimated. The importance of queuing analysis at the ASC level is that the total queues caused by the various tributaries all directly affect the storage capacity required at the ASC. If traffic volumes increase in the future, the tributaries, as the end/entry point in the system, will feel the full impact of the increased loads. The traffic destined for tributaries queues up at the parent ASC.

Through employment of this analysis tool, the present tributary utilization can be ascertained and, if it is reaching a high percentage, an upgrading of equipment capability can be considered. In addition, by running the program on predicted figures the effects on the tributaries and the ASC can be estimated.

B. EXPERIMENTAL PROCEDURE

Every ASC maintains data on the number of messages and lineblocks received from and transmitted to their associated tributaries and the other ASCs. The totals are compiled and published monthly in the ASC Communications Operating Performance Summary [Refs. 17 and 19]. A sample page is provided in Appendix C.

A COBOL computer program, see Computer Program Section, page 80, was developed by the author to perform the queuing analysis of all ASC

tributaries for a particular month. The input data for each tributary consisted of a Hollerith Card which identified the tributary by name and baud rate of the circuit plus the monthly totals of messages and lineblocks received. From this information the COBOL program determined the queue values for the tributary. The program generated, for each tributary, values for: (a) the percentage of facility utilization; (b) mean input rate, in messages per minute; (c) mean service time, in minutes per message; (d) mean number of transactions in process; (e) mean time in process, in minutes; (f) mean time waiting for processing, in minutes; and (g) mean number of transactions waiting to be processed.

If the values for facility utilization, mean input rate, and mean service time are known, then all other values can be derived from them. The following assumptions were made concerning this analysis: (a) the time between arrival of messages at the ASC is exponentially distributed; (b) service time is exponentially distributed; (c) there is no limit to the number of messages that can arrive or be waiting for processing; (d) incoming messages are served on a FIFO basis.

Facility utilization (UTIL) was computed by dividing the number of bits per minute received by the capacity of the circuit in bits per minute, derived from the baud rate of the circuit serving the tributary.

The mean input rate (MIR) was derived from the number of messages received divided by the number of minutes in the month, varying for 30 and 31 day months.

The mean service time (MST) was computed by dividing the mean number of bits per message by the transmission rate of the circuit in bits per minute.

Based on a single server model with exponentially distributed service time, the mean number of transactions in process (MNTP) was determined by dividing UTIL by one minus UTIL. The mean time in process (MTIP) was determined by dividing the MST by one minus UTIL. The mean time waiting for processing was determined by subtracting the MST from MTIP. The mean number of transactions waiting for processing was determined by subtracting UTIL from MNTP [Ref. 19].

C. INTERPRETATION OF RESULTS

The results of the tributary utilization program and interpretation thereof are summarized, using message traffic figures from the July 1972 ASC Communications Operating Performance Summary for the ASCs at McClellan AFB and Norton AFB for illustrative purposes. Observations and suggestions are made as to the possible uses of this type of output. A portion of the printout, generated by the computer program contained in the Computer Program Section, page 80, is contained in the Computer Output Section, page 76. Since COBOL is used as the programming language, format changes and other modifications, such as sorting and counting by utilization percentages, etc., can be easily made to vary the program as desired using the standard coding techniques associated with COBOL.

1. Tributary Utilization

The distribution of tributary utilization for McClellan and Norton for July 1972 is provided in figures 11 and 12 respectively. As can be readily seen, the bulk of McClellan tributary utilization percentages fell in the 0-5% range, with steadily decreasing numbers down to 25% and one tributary at the 45-50% level. Contrasting the McClellan utilization figures with the Norton figures, it is evident that the Norton ASC had less 0-5% tributaries and more tributaries spread over the range from 5-55% and one in the 70-75% range.

Norton ASC during this month experienced an overload condition and was forced to initiate emergency procedures. It is understood that the situation has been alleviated by the completed installation of a disc unit for intransit storage in place of the previous drum arrangement [Ref. 20]. The one tributary in the 70-75% range is the Message Center at the Naval Postgraduate School. During this period the Message Center was affected by a recently instituted policy concerning the weather messages addressed to the Fleet Numerical Weather Facility, one of the commands on their guard list. The extremes in traffic volumes and high utilization percentages were sufficient to justify a second Mode V terminal, which has been installed and became operational 18 January 1973 [Ref. 21].

Through use of the overall utilization histograms for each ASC an impression can be gained as to how busy each has been in comparison to the others. By computing and graphing these figures over a one year period the DCA Headquarters can obtain an impression of fluctuations in traffic volumes system-wide and by individual tributary.

At the ASC level, a monthly survey of their tributaries' utilizations, collected for a year or more, can provide a running record of which tributaries are consistently under-utilized, over-utilized, as well as those whose utilization is fluctuating or steady. From these initial indications, further examination of the tributary can determine if remedial action is warranted.

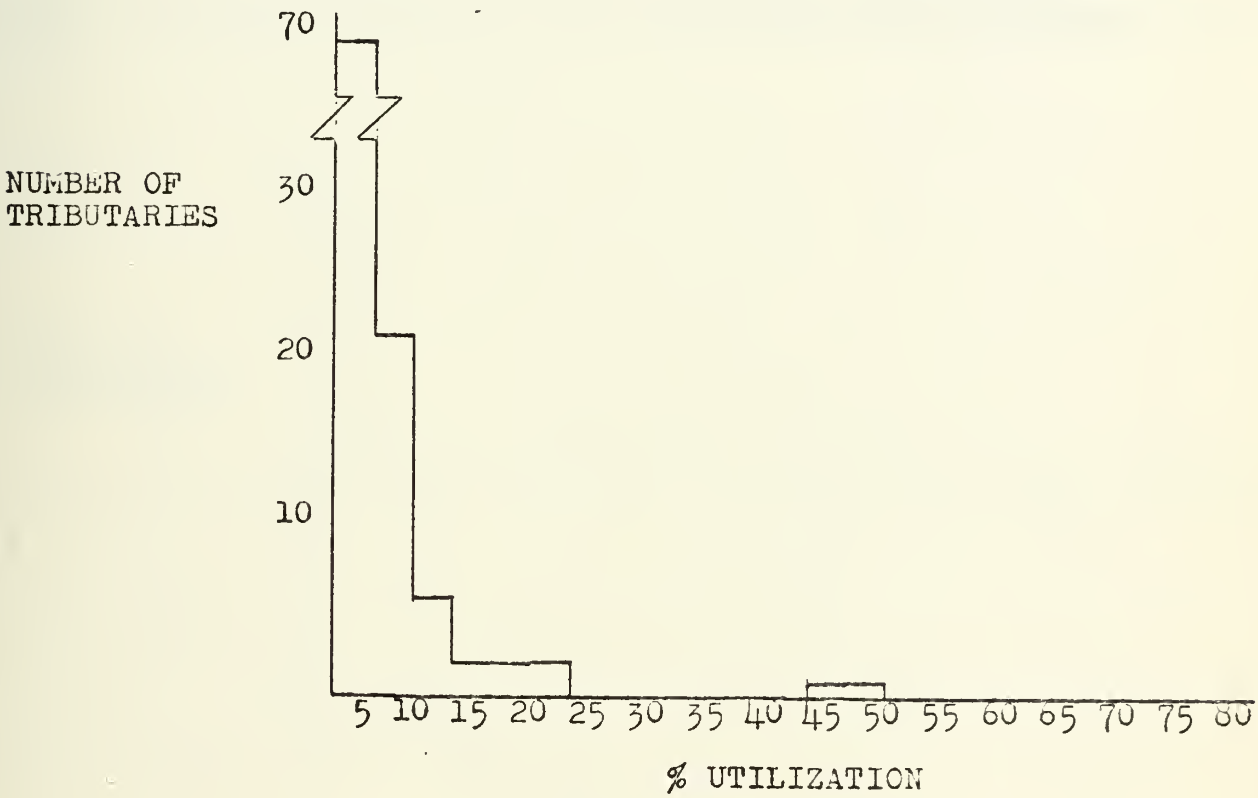


Figure 11. McClellan ASC Tributary Utilization Histogram.

An important consideration illuminated in queuing theory is the fact that the message queue size starts to grow at an alarming rate for tributaries whose utilization percentage is greater than about eighty percent [Ref. 22]. Fortunately, only one tributary in the two ASCs surveyed was even approaching the eighty percent figure at this time. However,

what will the future hold? Just how much of an increase in traffic volumes can the system stand before tributary utilizations approach the eighty percent figure and form queues which exceed storage capacities of their parent ASCs? This thesis does not attempt to examine these questions in depth, but the author suggests that the expected increases in traffic volumes will be sufficient to overload the network in the not too distant future if a terminal modification is not forthcoming.

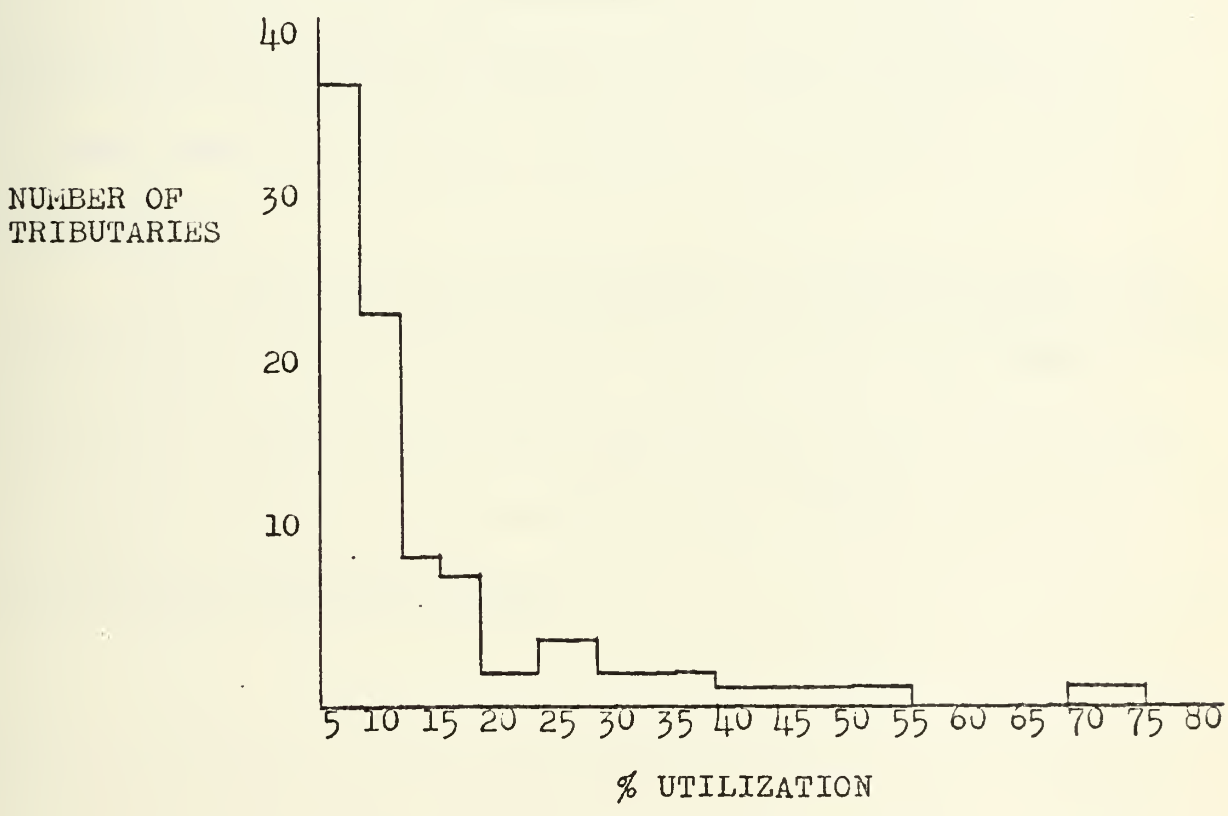


Figure 12. Norton ASC Tributary Utilization Histogram.

On the other end of the utilization spectrum, an examination of the computer printout of the McClellan tributary utilizations shows 21 tributaries with less than one percent utilization, several of which are

expensive high speed Mode I terminals. With utilizations that low it appears that the tributaries concerned could be candidates for a reduced capability or perhaps a geographic consolidation effort.

2. Usage of Other Queuing Information

An examination of the mean input rate in relation to the mean service time gives an indication of whether the traffic volume or the handling capability of the terminal or both are the major contributors to the tributary utilization percentages.

The mean number of transactions waiting for processing at the tributary gives an indication of the size of the queue at the parent ASC. The mean number of transactions in process is another indicator of terminal loading.

The mean time waiting for processing is related to the mean number of messages waiting at the ASC for tributary terminal availability. This can give some indication of the extent of delay in delivery a message can expect to experience in getting from the parent ASC through the output device at the tributary terminal.

VI. CONCLUSIONS

A. PROJECT APPLICATIONS

The interpretation of results of the CDP simulation and the tributary utilization program conducted previously shows what type of information these tools can provide for analyzing AUTODIN and other communications facilities. It is important at this point to expand on these specific appli-ations and present a synthesized description of how the models and results obtained can be used as a management tool in planning future communications facilities, such as AUTODIN, and in improving the operation of those already in existence.

As is apparent, the simulation dwells on the ASC CDP operation and the tributary utilization program analyzes the associated tributaries. With these two tools, the portion of the AUTODIN most in need of analysis - the ASC and tributaries - can be examined. For example, the simulation showed that the CDP was more than adequate to handle present traffic loads and probably would be able to handle expected future traffic volumes. However, as indicated in the tributary utilization program, some tributaries will not be able to withstand an appreciable rise in traffic volume, with the current configuration, without causing a considerable load on the ASC and a degradation in tributary performance. When the tributary utilization percentages begin to approach the eighty percent mark, traffic stored in the ASC intransit storage devices will begin to grow and will soon fill the available storage locations.

The future development of the tributary terminal configuration and equipment should relieve the channel congestion in order to be able to accommodate increases in traffic volumes. Among the possibilities available are: a reduction in mean service time and wait time through development and installation of higher speed terminal devices; shorten the length of the messages through elimination of unnecessary administrative checks and redundancy features; and add tributary channels and send a portion of the traffic over each. A final possibility would be to automate the current manually controlled and activated Alt-Route plan, through incorporation in the software of the CDP. This would alleviate delays causing build up in intransit storage aggravated by manual operation of the Alt-Route program. In addition, an automated Alt-Route plan would enable a more timely response in delivering traffic under alternate route conditions.

Final selection of alternative actions to solve the tributary terminal configuration and equipment problem should be accompanied by an in depth analysis of the economic considerations. For example, the relative cost of expansion of the MMU versus increasing the utilization capacity of one or more tributaries should be examined. Also the economic value of reducing the capabilities of an existing tributary because it is operating at a very low level should consider the capital cost versus future maintenance.

How can the simulation and tributary utilization program help in solving message congestion problems, in addition to giving an indication

that a problem exists in the first place? There are three ways in which the tools may be used to help provide answers.

a. Vary the input data

By using different input data rates the effect on the simulation of varying traffic loads can be ascertained. Varying the input data (the number of messages and line-blocks) for the tributary utilization program will give different queuing values, such as percent utilization under differing traffic loads and message size .

b. Vary The Tributary Receive Capability

By varying the capability of the tributaries to receive traffic by holding a specific percentage of traffic in the MMU, while holding the input data rate fixed, the impact of tributary outages and Alt-Route assignment can be estimated.

c. Vary Both Input Data And Program Logic

With the two models utilized together in such a way as to increase the volume of traffic generated by the simulation and changing the characteristics of the time spent in intransit storage to reflect a specified percent utilization situation at one or more tributaries, as computed by the tributary utilization program, the actual impact of the increase in traffic volume on the ASC as described above can be estimated. However, it should be pointed out that, virtually the same results can be achieved in a single program, by incorporating within the simulation program, a routine to create backlogs at the ASC due to the inability of the tributary to absorb messages at the rate which the ASC can provide. This has not been explored in detail in this thesis.

B. FUTURE ROLES

The simulation model and tributary utilization program, although not specifically demonstrated in each way here, can be used in may different roles in improving ASC and AUTODIN system design and efficiency. The following is a partial list of functions for which this and similar simulation models can be used.

1. Aiding Problem Definition

The manager and developer obtains useful information even before the simulation is run due to the analysis which is necessary in order to construct a model. The constructing of the model forces the manager to state clearly and explicitly his understanding of the system.

2. Isolation of Critical Areas

Systematic testing of the model provides valuable insights into the most sensitive and critical areas of system performance. By using the available data the model can be tested and examined for errors in data values, logic, and functions. Upon satisfactory completion of the model, actual testing of the system with data values ranging from optimistic to pessimistic can give indications of areas where system performance is weak and where changes are needed or additional analysis is required.

3. Ascertaining Configuration Possibilities

Since the AUTODIN is a relatively complex real-time computer system, there is a variety of design, equipment and configuration possibilities available. Once a model is developed, it can be used to evaluate

possible configuration changes. This is vastly superior to actually carrying out the modification of the system and then ascertaining the effect.

The tools developed and discussed in this thesis permit a limited analysis of the tributaries and CDP. As follow-on efforts provide tools for analyzing additional portions of the AUTODIN ASC, more comprehensive analyses can be made. Hopefully, one day all the segments will be completed and can be put together so that their interaction can give some indication of overall system performance.

APPENDIX A

GPSS

MODEL DESCRIPTION

The basic GPSS building units employed in this simulation are of these three types: facilities, storages, and transactions. A facility can simulate a single server, and may represent such components as transfer channels. A storage can simulate multiple servers or storage units, and may represent structures such as the CDP, High Speed Memory (HSM) and intransit storage unit (MMU). A transaction is a discrete unit of traffic that interacts by utilizing facilities and entering storages. In this simulation model the transaction is a message [Ref. 23].

To structure entities and define a logical flow of transactions, the GPSS language contains basic operations, such as "seize facility", and "enter storage." Each operation is called a block, and a network of operations is called a block diagram. The correspondence to ordinary block diagrams or flow charts is deliberate. Transactions are caused by the GPSS program to "flow" through the diagram from block to block, automatically following the path indicated and executing the operations as they are encountered [Ref. 24]. The block diagram of this GPSS simulation is contained in Appendix B and the actual computer program is contained in the Computer Program Section, page 77.

At times, GPSS was tedious to work with, in the development of the simulation model, due to the limitations and characteristics of the

language e.g., variables must be integer values and cannot be multiplied by a decimal number. In some instances over specialization had to be programmed around to achieve the desired model (the automatic computation of transit times of transactions through the model never produced feasible figures and an alternate means of tabulating the information using Transaction Parameters had to be devised.)

The data which can be obtained from a relatively simple GPSS program can be quite extensive or very limited depending on the needs of the user. Some of the more important items of output data compiled in this simulation were values for: Relative and Absolute Clock, Block Count, User Chain, Facility, Storage, Savevalues, Queue, and Tables, as ordered by the program. Various statistics are automatically computed, calculated and printed out for the blocks in the GPSS program. A sample output for the simulation is contained in the Computer Output Section, page 74, and would be a helpful reference in the following discussion of the output data.

The Relative and Absolute Clock values record how far forward in time a system has moved. The simulation clock is automatically set to a value of zero when the simulation starts and the duration of the run may be controlled by a special simulation termination counter. GPSS is a "next event" simulator which means that after a model has been fully updated at a given point in simulation time, the simulated clock is advanced to the nearest time at which another event is scheduled to occur. The millisecond is the unit of time implicit in this model. One of the

most important and difficult parts of the simulation was the development of one time standard throughout. If accurate, meaningful results are to be expected, then all advances, delays and clocks must be set to a uniform time standard. Initially, this simulation was written based on microseconds as a standard. This proved to be extremely good in programming the equipment and process characteristics of the system, most of which operate at speeds in the microsecond range. Unfortunately, at the microsecond level the maximum space available for the clock value, 11 decimal places, precluded running the simulation for more than one hour. In addition, a 30 minute simulation run at the microsecond standard required about 8 minutes of computer time.

Thus the millisecond was settled upon as a time standard for the simulation. The computer time was drastically reduced and the amount of real time which could be simulated was greatly increased. Where at the microsecond level only an hour could be simulated, at the millisecond level a month could be simulated within clock space. A full day simulation required about 30 minutes of computer time. There was, however, a trade-off in that the parameters and characteristics of the simulation could not be controlled to the minute values that were possible at the microsecond level, but it was determined that the benefits far outweighed this draw-back.

The Block Count is a summary of the number of transactions which, at the completion of the simulation run, currently reside in a specific block as well as a total of all transactions which have passed through the

block. The blocks are numbered in ascending order and correspond to the serial numbering of the blocks in the simulation program. This feature gives a good picture of what transpired, where the transactions went, and what the simulation did.

The User Chain is rather complicated to describe in depth but suffice it to say in this simulation that a user chain was created to accommodate transactions in the MMU waiting for an outgoing channel, where, upon availability, they were transferred from the MMU to the HSM via a transfer channel. The insertion of transactions in a user chain conserves the limited space in the computer allocated for active transactions by placing them in an inactive status while in a user chain.

The facility data consists of average utilization, in a decimal value, the number of transactions which entered the facility and the average time each transaction spent in the facility. Each facility in the simulation program is identified by a number and by keying the facility number to the CDP component/function which it represents the values can be correlated to a component function. A table of Facility numbers and the CDP component/function to which they correspond is provided in figure 13.

The Storage, although similar to a Facility, has a capacity associated with it and therefore contains the same information as does the facility plus a description of the Capacity of the Storage, its Average Contents, Current Contents, and Maximum Contents. A table of Storage numbers and the CDP component/function to which they correspond is provided in figure 14.

FACILITY NUMBER	CDP COMPONENT/FUNCTION
1	ADU/CDP Transfer Channel
2	CDP HSM For Input Processing
3	If MMU Full Divert to Magnetic Tape
4	CDP/MMU Transfer Channel
5	High Speed ADU Zone Queue In MMU
6	Medium Speed ADU Zone Queue In MMU
7	Low Speed ADU Zone Queue In MMU
8	MMU/CDP Transfer Channel
9	CDP HSM For Output Processing
10	CDP/ADU Transfer Channel

Figure 13. Facility Numbers and Corresponding CDP Component/Function.

STORAGE NUMBER	CDP COMPONENT/FUNCTION
2	HSM Storage For Input Processing
3	MMU Intransit Storage
4	HSM Storage For Output Process

Figure 14. Storage Numbers and Corresponding CDP Component/Function.

The Savevalues in GPSS are a series of storage locations whose contents can be referenced from any point in the model. In this simulation Savevalues were assigned to the Overflow Magnetic Tape and the Tributary Traffic held at the ASC due to inactive or inoperative tributary circuits. These components were assigned Savevalues 1 and 2

respectively. As can be seen from the Simulation print-out, located in Computer Output Section on page 74, Savevalues are only printed when non-zero, thus the reason for the appearance of Savevalue 2 only.

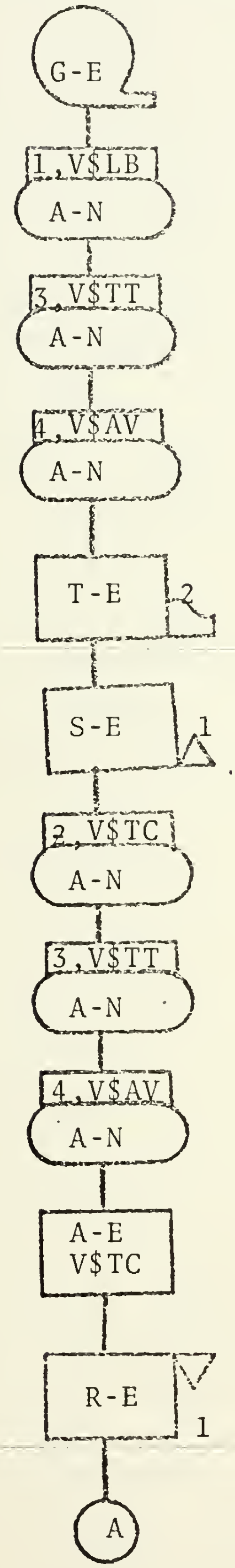
Queues were utilized in this simulation model to give an indication of the number of transactions which had to wait for a specific facility or storage and the average time that was required. Queues were set up to determine waiting times for Input processing, Intransit Storage transfer channel availability and Output Processing. These queues were assigned numbers 2, 4, and 9 respectively in the program and the output section.

Tables were set up for the purpose of showing the various distributions of message size, CDP transit times, message processing times, and input and output processing times. The identification of tables is shown in figure 15. All times are in milliseconds so a shift of three decimal places to the left is necessary to determine seconds.

TABLE	IDENTIFICATION
1	Message Processing Times
2	Message Size in Lineblocks
3	Input Processing Times
4	Output Processing Times
5	Effective CDP Message Processing Time

Figure 15. Table Numbers and Identification

APPENDIX B
BLOCK DIAGRAM OF SIMULATION MODEL



CREATE INCOMING MSG EVERY 2.8 SECONDS, INTERARRIVAL TIME EXPONENTIALLY DIST.

MESSAGE SIZE IN LINEBLOCK, ASSIGN TO PARAMETER 1.

ASSIGN TRANSIT TIMES TO PARAMETER 3.

ASSIGN MSG PROCESSING TO PARAMETER 4.

TABULATE DISTRIBUTION OF MSG SIZES. ASSIGN TABLE 2.

SEIZE ADU/CDP TRANSFER CHANNEL.

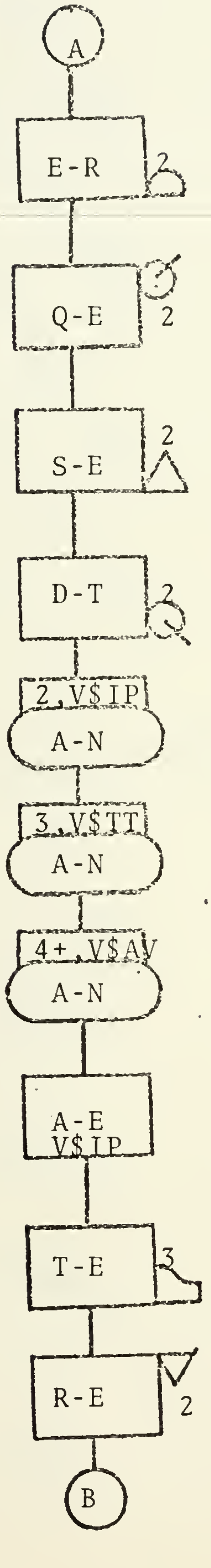
ASSIGN TIME SPENT IN TRANS. CHANNEL TO VARIABLE.

ADD TIME IN TRANSFER CHANNEL TO TRANSIT TIME.

ADD ADVANCE TO MSG PROCESSING TIME.

TIME SPENT IN TRANSFER CHANNEL

RELEASE TRANSFER CHANNEL.



ENTER HSM FOR INPUT PROCESS.

QUEUE IN CDP HSM FOR INPUT PROCESSING.

SEIZE CDP HSM FOR INPUT PROCESSING.

DEPART QUEUE FOR INPUT PROCESSING.

ASSIGN TIME SPENT IN INPUT PROCESSING TO VARIABLE.

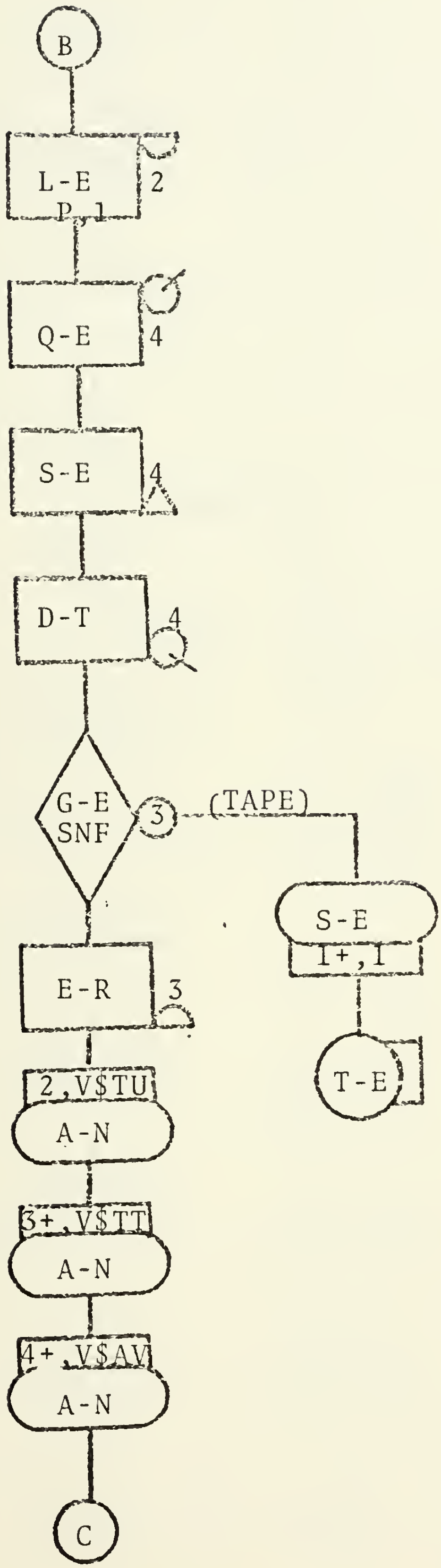
ADD TIME IN INPUT PROCESSING TO TRANS TIME.

ADD ADVANCE TO MSG PROCESSING TIME.

TIME SPENT IN INPUT PROCESSING.

TABULATE DISTRIBUTION OF INPUT PROCESSING TIME.

RELEASE CDP FROM INPUT PROCESSING.



LEAVE CDP AFTER INPUT PROCESSING.

QUEUE FOR TRANSFER TO MMU.

SEIZE TRANSFER CHANNEL TO MMU.

DEPART QUEUE FOR TRANSFER TO MMU.

GATE TO OVERFLOW TAPE.

SAVEVALUE LINEBLOCKS IN MESSAGE.

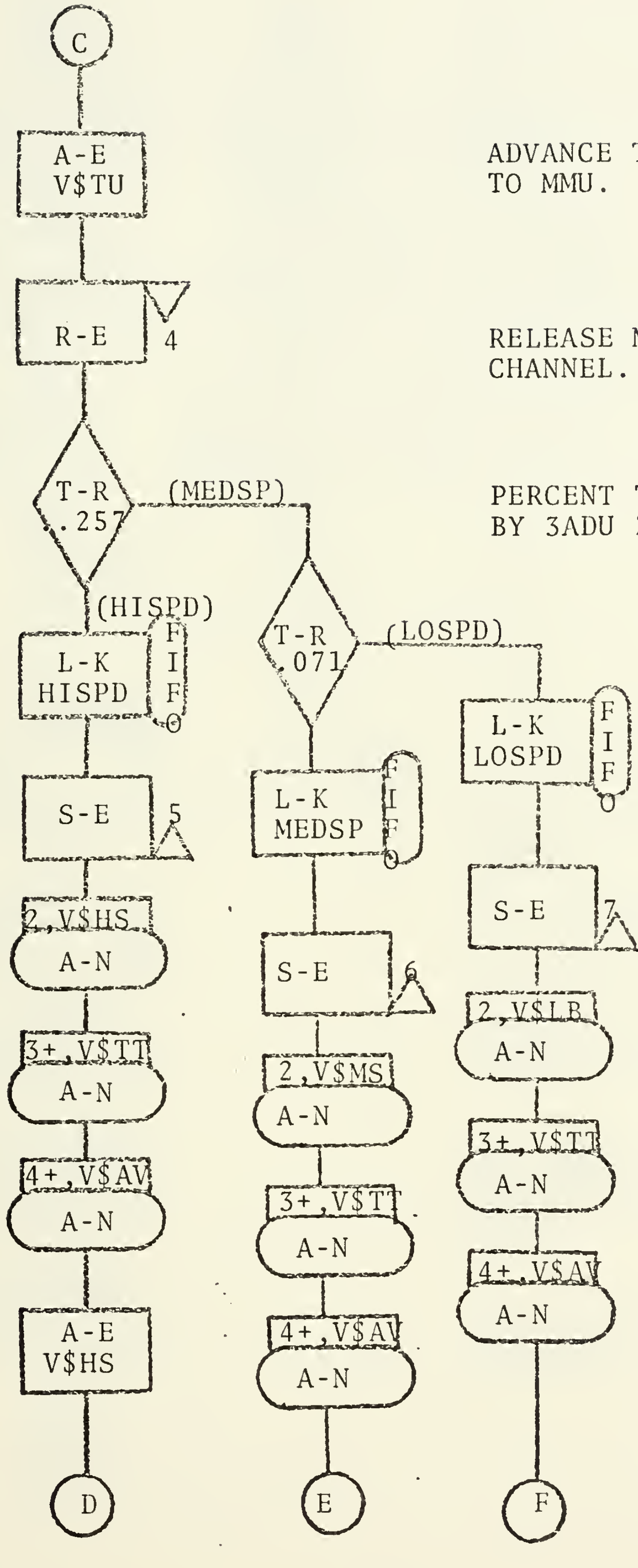
ENTER MMU TAKE UP P1 STORE.

TERMINATE TRANSACTIONS .

ASSIGN TIME SPENT IN MMU TRANSFER TO VARIABLE.

ADD TIME IN MMU TRANSFER TO TRANSIT TIME.

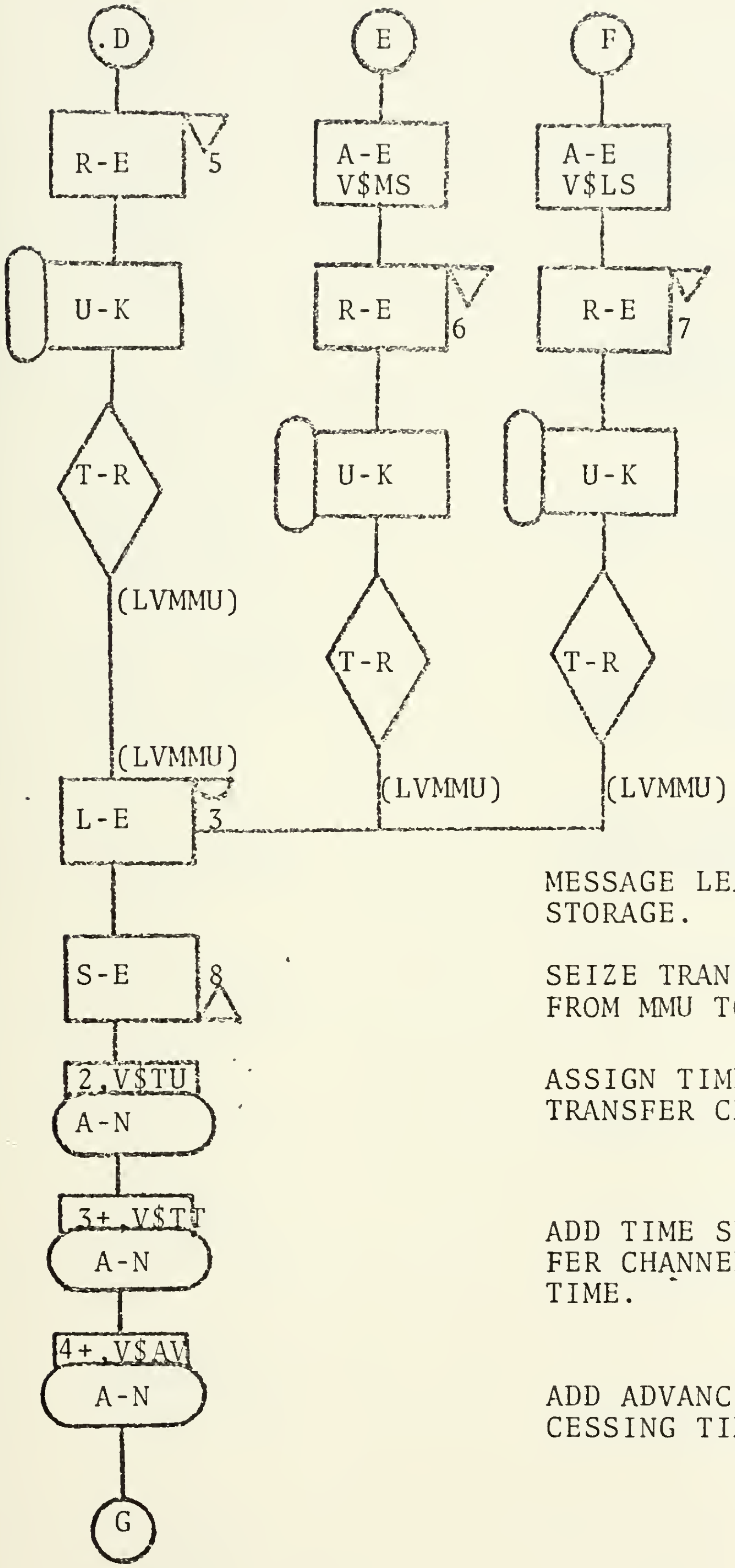
ADD ADVANCE TO MSG PROCESSING TIME.



ADVANCE TIME TO TRANSFER TO MMU.

RELEASE MMU TRANSFER CHANNEL.

PERCENT TRAFFIC HANDLED BY 3ADU ZONES.



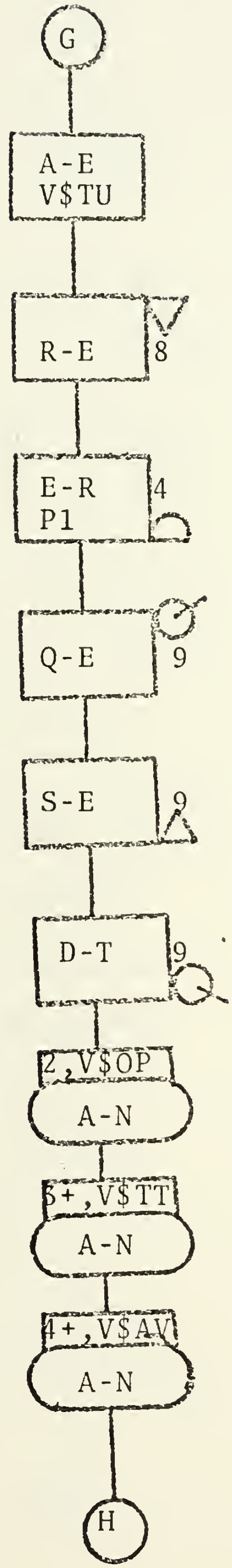
MESSAGE LEAVES MMU STORAGE.

SEIZE TRANSFER CHANNEL FROM MMU TO CDP.

ASSIGN TIME SPENT IN TRANSFER CHAN TO VARIABLE.

ADD TIME SPENT IN TRANSFER CHANNEL TO TRANSIT TIME.

ADD ADVANCE TO MSG PROCESSING TIME.



ADVANCE TIME TO TRANSFER FROM MMU TO CDP.

TRANSFER FROM MMU TO CDP COMPLETED.

ENTER CDP HSM FOR OUTPUT PROCESSING.

QUEUE IN HSM FOR OUTPUT PROCESSING.

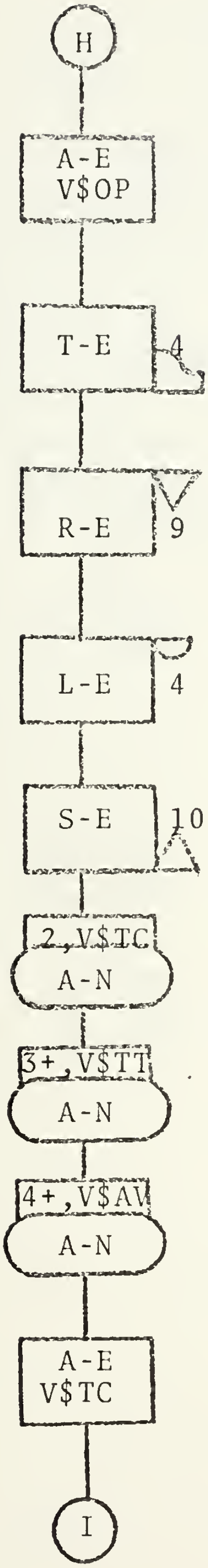
SEIZE HSM FOR OUTPUT PROCESSING.

DEPART QUEUE FOR HSM.

ASSIGN OUTPUT PROCESSING TIME TO VARIABLE.

ADD TIME SPENT IN OUTPUT PROCESSING TO TRANSIT TIME.

ADD ADVANCE TO MESSAGE PROCESSING TIME.



ADVANCE TIME SPENT IN OUTPUT PROCESSING.

TABULATE DISTRIBUTION OF OUTPUT PROCESSING TIME.

RELEASE HSM FROM OUTPUT PROCESSING.

LEAVE HSM AFTER OUTPUT PROCESSING.

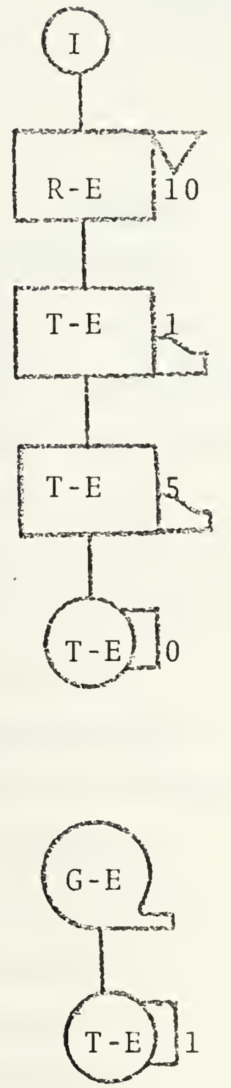
SEIZE TRANSFER CHANNEL CDP TO ADU.

ASSIGN TIME SPENT IN TRANSFER CHANNEL TO VARIABLE.

ADD TIME SPENT IN TRANSFER CHANNEL TO TRANSIT TIME.

ADD ADVANCE TO MESSAGE PROCESSING TIME.

ADVANCE TIME SPENT IN TRANSFER CHANNEL.



RELEASE CDP, TRANSFER COMPLETED.

TABULATE TRANSIT TIME.

TABULATE MESSAGE PROCESSING TIME.

TERMINATE TRANSACTION.

CLOCK FOR SETTING TIME OF SIMULATION RUN.

TERMINATE SIMULATION RUN.

APPENDIX C
EXTRACT FROM ASC COMMUNICATIONS
OPERATING PERFORMANCE SUMMARY

TRIBUTARY TRAFFIC LINEBLOCKS

SEP 1972

R/I	LOCATION	Chnl	Send Msgs	Send Lineblocks	Receive Msgs	Receive Lineblocks
2400 Baud Tributaries						
BSA	Oakland Army Term, Ca.	254	11329	1275547	16540	703069
DAA	Ogden Defense Depot, Ut.	248	3049	868747	4610	694162
EBA	North American Acft, L.A., Ca.	251	308	5011	721	15377
RUCS	Offutt AFB, Nb.	261	1463	226534	30681	815244
ZZA	DoD AAS, Defense Depot, Tracy, Ca.	266	170358	4462707	20040	3990904
RUVN	BCC, McClellan AFB, Ca.	263	6922	492040	30319	1827267
RUVH	Hill AFB, Ut.	262	6385	591733	21680	938049
1200 Baud Tributaries						
AFA	Long Beach NAVMSGCEN, Ca.	260	6798	176745	17416	334870
BFA	NAS Alameda, Ca.	235	2477	517337	13662	255004
BHA	Presidio, San Fran, Ca.	091	4149	354791	8148	317628
BKA	Elmendorf JCC, Ak.	063	2299	168894	12686	415379
BWA	Bremerton, Wa.	244	4857	178547	15100	238260
DDA	Beale AFB, Ca.	062	2729	128633	1406	59264
DTA	Mather AFB, Ca.	264	2608	150425	7254	171228
EAA	Burlingame, Ca.	245	1368	17705	1457	47164
EFA	Travis AFB, Ca.	089	8741	466746	25238	628963
EKA	Oakland Naval Yard, Ca.	271	12709	832578	27801	804431
EWA	Hamilton AFB, Ca.	265	2730	99491	8343	157163
FDA	Fort Lewis, Wa.	090	1374	100152	2485	111316
FWA	Sacto Army Depot, Ca.	253	2152	235769	4234	192563
MFA	NAVCOMSTA, Stockton, Ca.	246	14620	217402	45433	779700
PLA	Presidio, San Fran, Ca.	092	821	101259	3848	159404

COMPUTER OUTPUT

RELATIVE CLOCK 86400000 ABSOLUTE CLOCK 86400000

BLOCK COUNTS

BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL
1	0	30129	11	0	30129	21	0	30129	31	0	30129	41	0	22465
2	0	30129	12	0	30129	22	0	30129	32	0	30129	42	0	22465
3	0	30129	13	0	30129	23	0	30129	33	0	30129	43	0	7664
4	0	30129	14	0	30129	24	0	30129	34	0	22465	44	0	7179
5	0	30129	15	0	30129	25	0	30129	35	0	22465	45	0	7116
6	0	30129	16	0	30129	26	0	30129	36	0	22465	46	0	7116
7	0	30129	17	0	30129	27	0	30129	37	0	22465	47	0	7116
8	0	30129	18	0	30129	28	0	30129	38	0	22465	48	0	7116
9	0	30129	19	0	30129	29	0	30129	39	0	22465	49	0	7116
10	0	30129	20	0	30129	30	0	30129	40	0	22465	50	0	7116

BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL
51	0	7116	61	0	485	71	0	30066	81	0	30066	91	0	0
52	0	7116	62	0	485	72	0	30066	82	0	30066	92	0	63
53	0	7116	63	0	30066	73	0	30066	83	0	30066	93	0	63
54	0	485	64	0	30066	74	0	30066	84	0	30066	94	0	100
55	0	485	65	0	30066	75	0	30066	85	0	30066	95	0	100
56	0	485	66	0	30066	76	0	30066	86	0	30066			
57	0	485	67	0	30066	77	0	30066	87	0	30066			
58	0	485	68	0	30066	78	0	30066	88	0	30066			
59	0	485	69	0	30066	79	0	30066	89	0	30066			
60	0	485	70	0	30066	80	0	30066	90	0	0			

USER CHAIN	TOTAL ENTRIES	AVERAGE TIME/TRANS	CURRENT CONTENTS	AVERAGE CONTENTS	MAXIMUM CONTENTS
HISPD	281	37.654		.000	2
MEDSP	63	93.952		.000	2
LOSPD	1	8.000		.000	1

FACILITY	AVERAGE UTILIZATION	NUMBER ENTRIES	AVERAGE TIME/TRAN	SEIZING TRANS. NO.	PREEMPTING TRANS. NO.
1	.000	30129	1.892		
2	.047	30129	136.669		
4	.000	30129	.282		
5	.008	22465	32.537		
6	.008	7116	98.666		
7	.001	485	186.903		
8	.000	30066	.282		
9	.023	30066	66.698		
10	.000	30066	1.891		

STORAGE	CAPACITY	AVERAGE CONTENTS	AVERAGE UTILIZATION	ENTRIES	AVERAGE TIME/TRAN	CURRENT CONTENTS	MAXIMUM CONTENTS
2	5461	1.718	.000	982301	151.135		453
3	64512	916.224	.014	982301	80588.125	2207	2479
4	5461	.788	.000	980094	69.534		279

CONTENTS OF FULLWORD SAVEVALUES (NON-ZERO)

SAVEVALUE NR.	VALUE	NR.	VALUE	NR.	VALUE	NR.	VALUE	NR.	VALUE
2	2207								

QUEUE	MAXIMUM CONTENTS	AVERAGE CONTENTS	TOTAL ENTRIES	ZERO ENTRIES	PERCENT ZEROS	AVERAGE TIME/TRANS	$AVERAGE TIME/TRANS	TABLE NUMBER	CURRENT CONTENTS
2	4	.003	30129	28744	95.4	9.002	195.848		
4	1	.000	30129	30114	99.9	.000	1.466		
9	3	.000	30066	29262	97.3	2.775	103.803		

$AVERAGE TIME/TRANS = AVERAGE TIME/TRANS EXCLUDING ZERO ENTRIES

TABLE 1

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
30066	2844.376	2380.000	85519024.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
0	0	.00	.0	100.0	-.000	-1.195
500	1941	6.45	6.4	93.5	.175	-.985
1000	4252	14.14	20.5	79.4	.351	-.774
1500	4288	14.26	34.8	65.1	.527	-.564
2000	3510	11.67	46.5	53.4	.703	-.354
2500	2887	9.60	56.1	43.8	.878	-.144
3000	2335	7.76	63.9	36.0	1.054	.065
3500	1997	6.64	70.5	29.4	1.230	.275
4000	1749	5.81	76.3	23.6	1.406	.485
4500	1460	4.85	81.2	18.7	1.582	.695
5000	1194	3.97	85.1	14.8	1.757	.905
5500	968	3.21	88.4	11.5	1.933	1.115
6000	670	2.22	90.6	9.3	2.109	1.325
6500	523	1.73	92.3	7.6	2.285	1.535
7000	439	1.46	93.8	6.1	2.460	1.746
7500	335	1.11	94.9	5.0	2.636	1.956
8000	299	.99	95.9	4.0	2.812	2.166
8500	222	.73	96.6	3.3	2.988	2.376
9000	176	.58	97.2	2.7	3.164	2.586
9500	128	.42	97.6	2.3	3.339	2.796
10000	116	.38	98.0	1.9	3.515	3.006
10500	98	.32	98.4	1.5	3.691	3.216
11000	82	.27	98.6	1.3	3.867	3.426
11500	67	.22	98.9	1.0	4.043	3.636
12000	61	.20	99.1	.8	4.218	3.846
12500	60	.19	99.3	.6	4.394	4.056
13000	39	.12	99.4	.5	4.570	4.267
13500	47	.15	99.5	.4	4.746	4.477
14000	28	.09	99.6	.3	4.921	4.687
14500	16	.05	99.7	.2	5.097	4.897
15000	23	.07	99.8	.1	5.273	5.107
OVERFLOW	56	.18	100.0	.0		
AVERAGE VALUE OF OVERFLOW		16177.85				

TABLE 2

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
30129	32.603	33.187	982301.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
0	0	.00	.0	100.0	-.000	-.982
5	5053	16.77	16.7	83.2	.153	-.831
10	3592	11.92	28.6	71.3	.306	-.681
15	2975	9.87	38.5	61.4	.460	-.530
20	2631	8.73	47.2	52.7	.613	-.379
25	2186	7.25	54.5	45.4	.766	-.229
30	1914	6.35	60.9	39.0	.920	-.078
35	1576	5.23	66.1	33.8	1.073	.072
40	1515	5.02	71.1	28.8	1.226	.222
45	1223	4.05	75.2	24.7	1.380	.373
50	1019	3.38	78.6	21.3	1.533	.524
55	930	3.08	81.6	18.3	1.686	.674
60	784	2.60	84.2	15.7	1.840	.825
65	630	2.09	86.3	13.6	1.993	.976
70	614	2.03	88.4	11.5	2.147	1.126
75	522	1.73	90.1	9.8	2.300	1.277
80	403	1.33	91.4	8.5	2.453	1.428
85	338	1.12	92.6	7.3	2.607	1.578
90	302	1.00	93.6	6.3	2.760	1.729
95	285	.94	94.5	5.4	2.913	1.880
100	243	.80	95.3	4.6	3.067	2.030
105	207	.68	96.0	3.9	3.220	2.181
110	134	.44	96.5	3.4	3.373	2.332
115	166	.55	97.0	2.9	3.527	2.482
120	100	.33	97.3	2.6	3.680	2.633
125	103	.34	97.7	2.2	3.833	2.784
130	94	.31	98.0	1.9	3.987	2.934
135	65	.21	98.2	1.7	4.140	3.085
140	67	.22	98.4	1.5	4.294	3.236
145	54	.17	98.6	1.3	4.447	3.386
150	62	.20	98.8	1.1	4.600	3.537
OVERFLOW	342	1.13	100.0	.0		
AVERAGE VALUE OF OVERFLOW		185.15				

TABLE 3

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
30129	138.160	180.375	4162640.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
0	752	2.49	2.4	97.5	-.000	-.765
500	27961	92.80	95.3	4.6	3.618	2.006
1000	1240	4.11	99.4	.5	7.237	4.776
1500	176	.58	100.0	.0	10.856	7.550

REMAINING FREQUENCIES ARE ALL ZERO

TABLE 4

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
30066	65.765	96.062	1977314.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
0	1294	4.30	4.3	95.6	-.000	-.684
500	28537	94.91	99.2	.7	7.602	4.520
1000	219	.72	99.9	.0	15.205	9.725
1500	16	.05	100.0	.0	22.808	14.930

REMAINING FREQUENCIES ARE ALL ZERO

TABLE 5

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
30066	259.127	216.062	7790939.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
0	0	.00	.0	100.0	-.000	-1.199
500	26581	88.40	88.4	11.5	1.929	1.114
1000	3088	10.27	98.6	1.3	3.859	3.428
1500	380	1.26	99.9	.0	5.788	5.743
2000	17	.05	100.0	.0	7.718	8.057

REMAINING FREQUENCIES ARE ALL ZERO

ASC MC CLELLAN AFB

TRIBUTARY ANALYSIS

TRIB NAME	FACILITY UTIL (.)	MEAN INPUT RATE (MSG/MIN)	MEAN SVC TIME (MIN/MSG)	MEAN NR TRANS IN PROCESS	MEAN TIME IN PROCESS (MIN)	MEAN TIME FOR PROCESS (MIN)	MEAN NR TRANS WAIT FOR PROCESS
OAKLND ARMY TERM	0.1377	0.2537	0.5004	0.1596	0.5803	0.0799	0.0219
OGDEN DEF DEP	0.0938	0.0683	1.2663	0.1035	1.3973	0.1310	0.0097
NOR AM AC L.A.	0.0005	0.0068	0.0723	0.0005	0.0723	0.0000	0.0000
OFFUTT AFB NB	0.0244	0.0327	0.6881	0.0250	0.7053	0.0172	0.0006
DEF DEP TRACY CA	0.4820	3.8162	0.1164	0.9305	0.2247	0.1083	0.4485
BCC MCCLND AFB	0.0531	0.1550	0.3159	0.0560	0.3336	0.0177	0.0029
HILL AFB UTAH	0.0639	0.1430	0.4118	0.0682	0.4399	0.0281	0.0043
NAVMSGCEN LBECH	0.0381	0.1522	0.2311	0.0396	0.2402	0.0091	0.0015
NAS ALAMEDA	0.1117	0.0554	1.8564	0.1257	2.0898	0.2334	0.0140
PRESIDIO SFRAN	0.0766	0.0929	0.7601	0.0829	0.8231	0.0630	0.0063
ELMENDORF JCC	0.0364	0.0515	0.6530	0.0377	0.6776	0.0246	0.0013
BREMERTON WASH	0.0385	0.1088	0.3267	0.0400	0.3397	0.0130	0.0015
BEALE AFB CA	0.0277	0.0611	0.4189	0.0284	0.4308	0.0119	0.0007
MATHER AFB CA	0.0324	0.0584	0.5126	0.0334	0.5297	0.0171	0.0010
BURLINGAME CA	0.0038	0.0036	0.1150	0.0038	0.1154	0.0004	0.0000
TRAVIS AFB CA	0.1008	0.1958	0.4746	0.1120	0.5278	0.0532	0.0112
NAV YD OAK CA	0.1798	0.2846	0.5823	0.2192	0.7099	0.1276	0.0394
HAMILTON AFB CA	0.0214	0.0611	0.3239	0.0218	0.3309	0.0070	0.0004
FT LEWIS WASH	0.0216	0.0307	0.6479	0.0220	0.6622	0.0143	0.0004
SACTO ARMY DEP	0.0509	0.0482	0.9738	0.0536	1.0260	0.0522	0.0027
NAVCOMSTA STOCK	0.0469	0.3275	0.1321	0.0492	0.1386	0.0065	0.0023
PRESIDIO SFRAN 2	0.0218	0.0183	1.0963	0.0222	1.1207	0.0244	0.0004
GEORGE AFB CA	0.0183	0.0555	0.3049	0.0186	0.3105	0.0056	0.0003
TRAVIS AFB 2	0.0330	0.0899	0.3387	0.0341	0.3502	0.0115	0.0011
CHEYENNE MT CO	0.0875	0.2296	0.3514	0.0958	0.3850	0.0336	0.0083
BOEING AC CO WAS	0.0493	0.0364	1.2468	0.0518	1.3114	0.0646	0.0025
LOCKEED SVALE CA	0.0059	0.0243	0.2246	0.0059	0.2259	0.0013	0.0000
FT ORD CA	0.0488	0.0444	1.0126	0.0513	1.0645	0.0519	0.0025
MCCHORD AFB WA	0.0864	0.0243	3.2703	0.0945	3.5795	0.3092	0.0081
NELLIS AFB NV	0.0737	0.0322	2.1087	0.0795	2.2764	0.1677	0.0058
CASTLE AFB CA	0.0914	0.0524	1.6070	0.1005	1.7686	0.1616	0.0091
ELLSWORTH AFB SO	0.0088	0.0596	0.1362	0.0088	0.1374	0.0012	0.0000
SHEMYA AK	0.0061	0.0130	0.4371	0.0061	0.4397	0.0026	0.0000
FAIRCHILD AFB	0.0103	0.0184	0.5202	0.0104	0.5256	0.0054	0.0001
WARREN AFB WY	0.0463	0.0825	0.5170	0.0485	0.5420	0.0250	0.0022
NSY SFRAN CA	0.0308	0.0490	0.5797	0.0317	0.5981	0.0184	0.0009
TRAVIS AFB 3	0.0818	0.0111	6.7736	0.0890	7.3770	0.6034	0.0072
FT RICHARDSON AK	0.0729	0.0130	5.1406	0.0786	5.5448	0.4042	0.0057
GLASGOW AFB MT	0.0068	0.0031	2.0261	0.0068	2.0399	0.0138	0.0000
BEALE AFB 2	0.0499	0.0177	2.5890	0.0525	2.7249	0.1359	0.0026
HONOLULU HI	0.0108	0.0246	0.4058	0.0109	0.4102	0.0044	0.0001
MINOT AFB ND	0.2443	0.0412	5.4549	0.3232	7.2183	1.7634	0.0789
KINGSLEY FIELD O	0.0088	0.0089	0.9056	0.0088	0.9136	0.0080	0.0000
MALSTROM AFB MT	0.2306	0.0617	3.4433	0.2997	4.4753	1.0320	0.0691
FT WAINRT AK	0.0610	0.0096	5.8245	0.0649	6.2028	0.3783	0.0039
PORTLND INT ARPT	0.0387	0.0211	1.6869	0.0402	1.7548	0.0679	0.0015
ASC SVC POSIT	0.0583	0.0643	0.8368	0.0619	0.8886	0.0518	0.0036
ELMENDORF MAC AK	0.0290	0.0420	0.6367	0.0298	0.6557	0.0190	0.0008
MCCHORD AFB 2	0.0342	0.0321	0.9808	0.0354	1.0155	0.0347	0.0012
MT HOME AFB ID	0.1014	0.0414	2.2546	0.1128	2.5090	0.2544	0.0114
DCASC PAO ALTO	0.0275	0.0314	0.8086	0.0282	0.8314	0.0228	0.0007
1965 NORTON AFB	0.0417	0.0583	0.6583	0.0435	0.6869	0.0286	0.0018
TRAVIS AFB	0.0570	0.0870	0.6044	0.0604	0.6409	0.0365	0.0034
NAVCOMSTA AOAK	0.0268	0.0312	0.7910	0.0275	0.8127	0.0217	0.0007
ELMENDORF OSI	0.0081	0.0060	1.2401	0.0081	1.2502	0.0101	0.0000
US ARMY OAK CA	0.0161	0.0145	1.0229	0.0163	1.0396	0.0167	0.0002
LUKE AFB	0.0087	0.0173	0.4669	0.0087	0.4709	0.0040	0.0000
NELLIS AFB NV	0.0094	0.0040	2.1317	0.0094	2.1519	0.0202	0.0000
FT MCARTHUR CA	0.0247	0.0188	1.2077	0.0253	1.2382	0.0305	0.0006
AFPRO SVALE CA	0.0082	0.0040	1.8746	0.0082	1.8900	0.0154	0.0000
USA CONRAD MT	0.0030	0.0024	1.1560	0.0030	1.1594	0.0034	0.0000
ASC SVC POSIT	0.0004	0.0003	1.1111	0.0004	1.1115	0.0004	0.0000
FAA FREMONT CA	0.0025	0.0030	0.7785	0.0025	0.7804	0.0019	0.0000
17 CG DIST AK	0.0700	0.0297	2.1731	0.0752	2.3366	0.1635	0.0052
MILL VALLEY CA	0.0107	0.0051	1.9436	0.0108	1.9646	0.0210	0.0001
CENVLE BCH CA	0.0078	0.0072	1.0008	0.0078	1.0086	0.0078	0.0000

COMPUTER PROGRAM

```
//     EXEC   GPSS
//GO.SYSIN  DD    *
        REALLOCATE STO,4,QUE,9,LOG,0,TAB,5,FUN,7,VAR,12,FSV,2,HSV,0
        SIMULATE
 EXPO   FUNCTION     RN3,C24
0,0/.1,.104/.2,.222/.3,.355/.4,.509/.5,.69/.6,.915/.7,1.2/.75,1.38
.8,1.6/.84,1.83/.88,2.12/.9,2.3/.92,2.52/.94,2.81/.95,2.99/.96,3.2
.97,3.5/.98,3.9/.99,4.6/.995,5.3/.998,6.2/.999,7/.9998,8
    1   FUNCTION     RN4,C10
.1,833/.2,769/.3,714/.4,667/.5,625/.6,588/.7,556/.8,526/.9,500/1,500
    2   FUNCTION     RN5,C11
0.1/.1,9/.2,17/.3,25/.4,33/.5,41/.6,49/.7,57/.8,65/.9,73/1,77
    3   FUNCTION     RN1,C10
0.1/.13,250/.27,500/.427,1000/.5,1794/.812,3000/.893,4000/.938,5000
.989,8000/.994,9000
    5   FUNCTION     RN3,C24
0,1/.1,3.43/.2,7.32/.3,11.71/.4,16.79/.5,22.77/.6,30.19/.7,39.6
.75,45.54/.8,52.8/.84,60.39/.88,69.96/.9,75.90/.92,83.16/.94,92.73
.95,98.67/.96,105.6/.97,115.50/.98,128.70/.99,151.80/.995,174.90/
.998,204.60/.999,231/.9998,264
    6   FUNCTION     RN1,C10
0,1/.02,25/.05,50/.104,100/.427,500/.683,1000/.891,2000/.964,3000
.9962,5000/.999,8000
    1   TABLE        P4,0,500,32                SET UP TABLE OF MSG TRANS TIME
    2   TABLE        P1,0,5,32                  SET UP TABLE OF MSG LB
    3   TABLE        V$IP,0,500,21              SET UP TABLE OF I/P PROCESS
    4   TABLE        V$OP,0,500,21              SET UP TABLE OF O/P PROCESS
    5   TABLE        P3,0,500,21                SET UP TABLE OF TRANS TIMES
    2   STORAGE      5461                       STORAGE AVAIL IN HSM FOR I/P
    3   STORAGE      64512                      CAPACITY OF MMU IN LB
    4   STORAGE      5461                       STORAGE AVAIL IN HSM FOR O/P
   IP   VARIABLE     (FN2*FN3)/FN1              I/P PROCESSING
   TC   VARIABLE     P1/14                      VAR TO CCMP TRANS CHAN ADU/CDP
   LB   VARIABLE     FN5
   TU   VARIABLE     P1/50                      VAR TO TRANS CDP/MMU
   OP   VARIABLE     (FN2*FN6)/FN1              O/P PROCESSING
   TP   VARIABLE     5+(P1/48)                  TAPE WRITING PER MSG
   HS   VARIABLE     P1                         HI SPD TRANS TIME
   MS   VARIABLE     3*P1                       MED SPD TRANS TIME
   LS   VARIABLE     6*P1                       LO SPD TRANS TIME
   TT   VARIABLE     P2                         VARIABLE TO HOLD TRANS TIMES
   AV   VARIABLE     P2*11                      COMP TRANS TIME PER MSG
        GENERATE     2857,FN$EXPO,,,,,F         CREATE INCOMING MSG EVY 2.8 SEC
        ASSIGN       1,V$LB                     CALCULATE NR LINEBLOCKS PER MSG
        ASSIGN       3,V$TT                     ASSIGN TRANS TIME TO PARAM 3
        ASSIGN       4,V$AV                     ASSIGN MSG TRANS TIME TO PAR4
        TABULATE     2                          TABULATE NR MSG LB DIST
        ENTER        2,P1                       ENTER HSM FOR I/P PROCESS
```

```
         ASSIGN     2,V$LS            ASSIGN LS TO VAR TO COMP AV
         ASSIGN     3+,V$TT           ADD LS TO TRANS TIME
         ASSIGN     4+,V$AV           ADD ADVANCE TO MSG TRANS TIME
         ADVANCE    V$LS              TIME SPENT IN LOSPD TRANSMISSION
         RELEASE    7                 RELEASE TRANS FACILITY
         UNLINK     LOSPD,WAIT3,1     UNLINK 1 MSG FROM QUEUE CHAIN
         TRANSFER   ,LVMMU            TRANSFER TO LVMMU BLOCK
LVMMU    LEAVE      3,P1              MSG LEAVES MMU STORAGE
         SEIZE      8                 TRANS CHAN MMU TO HSM
         ASSIGN     2,V$TU            ASSIGN TU TO VAR TO COMP AV
         ASSIGN     3+,V$TT           ADD TU TO TRANS TIME
         ASSIGN     4+,V$AV           ADD ADVANCE TO MSG TRANS TIME
         ADVANCE    V$TU              TIME RQRD TO TRANS MMU TO HSM
         RELEASE    8                 TRANS FM MMU TO HSM COMPLETE
         ENTER      4,P1              ENTER HSM FOR O/P PROCESS
         QUEUE      9                 QUEUE IN HSM FOR O/P PROCESS
         SEIZE      9                 SEIZE HSM FOR O/P PROCESS
         DEPART     9                 DEPT HSM QUEUE
         ASSIGN     2,V$OP            ASSIGN OP TO VAR TO COMP AV
         ASSIGN     3+,V$TT           ADD OP TO TRANS TIME
         ASSIGN     4+,V$AV           ADD ADVANCE TO MSG TRANS TIME
         ADVANCE    V$OP              TIME SPENT IN O/P PROCESS
         TABULATE   4                 TABULATE AMT O/P TIME
         RELEASE    9                 RELEASE HSM FROM O/P PROCESS
         LEAVE      4,P1              LV HSM AFTER O/P PROCESS
         SEIZE      10                SEIZE TRANS CHAN
         ASSIGN     2,V$TC            ASSIGN TC TO VAR TO COMP AV
         ASSIGN     3+,V$TT           ADD TC ADV TO TRANS TIME
         ASSIGN     4+,V$AV           ADD ADVANCE TO MSG TRANS TIME
         ADVANCE    V$TC              TIME IN TRANS CHAN
         RELEASE    10                RLSE CDP, TRANS COMPLETE
         TABULATE   1                 TABULATE TRANSIT TIME
         TABULATE   5                 TABULATE TRANS TIME PER MSG
         TERMINATE  0                 DECREMENT TRANSACTION BY 1 MSG
TAPE     SAVEVALUE  1+,P1             ENTER OVERFLOW TAPE STORAGE
         TERMINATE  0
HOLD     SAVEVALUE  2+,P1             HOLD TFC FOR DOWN CKT
         TERMINATE  0
         GENERATE   864000            SET UP FOR 1 DAY RUN STRT 100
         TERMINATE  1
         START      100
         END
```

```
         SEIZE      1                    SEIZE TRANSFER CHAN
         ASSIGN     2,V$TC               ASSIGN TC TO VAR TO COMP AV
         ASSIGN     3+,V$TT              ADD TC TO TRANS TIME
         ASSIGN     4+,V$AV              ADD ADVANCE TO MSG TRANS TIME
         ADVANCE    V$TC                 TIME SPENT IN TRANS CHAN
         RELEASE    1                    RELEASE TRANS CHAN
         QUEUE      2                    QUEUE FOR I/P PROCESSING
         SEIZE      2                    SEIZE CDP FOR I/P PROCESS
         DEPART     2
         ASSIGN     2,V$IP               ASSIGN IP TO VAR TO COMP AV
         ASSIGN     3+,V$TT              ADD IP TO TRANS TIME
         ASSIGN     4+,V$AV              ADD ADVANCE TO MSG TRANS TIME
         ADVANCE    V$IP                 TIME SPENT IN I/P PROCESS
         TABULATE   3                    TABULATE NR MS I/P TIME
         RELEASE    2                    RELEASE CDP FROM I/P PROCESS
         LEAVE      2,P1                 LV HSM AFTER I/P PROCESS
         QUEUE      4                    QUEUE FOR MMU TRANSFER
         SEIZE      4                    TRANS CHAN TO MMU
         DEPART     4                    DEPART QUEUE FOR MMU TRANS CHAN
         GATE SNF   3,TAPE               IF MMU FULL DIVERT TO OVT TAPE
         ENTER      3,P1                 ENTER MMU TAKE UP P1 NR LB
         ASSIGN     2,V$TU               ASSIGN TU TO VAR TO COMP AV
         ASSIGN     3+,V$TT              ADD TU ADV TO TRANS TIME
         ASSIGN     4+,V$AV              ADD ADVANCE TO MSG TRANS TIME
         ADVANCE    V$TU                 TIME RORD TO TRANSFER TO MMU
         RELEASE    4                    RELEASE MMU TRANS CHAN
         TRANSFER   .257,,MEDSP          PROB .257 MSG WILL NOT GO HISPD
         LINK       HISPD,FIFO,WAIT1     CREATE HISPD USER CHAIN
WAIT1    SEIZE      5                    SEIZE QUEUE CHAIN
         ASSIGN     2,V$HS               ASSIGN HS TO VAR TO CCMP AV
         ASSIGN     3+,V$TT              ADD HS ADV TO TRANS TIME
         ASSIGN     4+,V$AV              ADD ADVANCE TO MSG TRANS TIME
         ADVANCE    V$HS                 TIME SPENT IN HISPD TRANSFER
         RELEASE    5                    RELEASE QUEUE CHAIN
         UNLINK     HISPD,WAIT1,1        MSG RELEASED FROM CHAIN
         TRANSFER   ,LVMMU               TRANSFER TO LVMMU BLOCK
MEDSP    TRANSFER   .071,,LCSPD          PROB .071 MSG WILL NOT GO MEDSP
         LINK       MEDSP,FIFO,WAIT2     CREATE MEDSP USER CHAIN
WAIT2    SEIZE      6                    SEIZE TRANSMISSION FACILITY
         ASSIGN     2,V$MS               ASSIGN MS TO VAR TO COMP AV
         ASSIGN     3+,V$TT              ADD MS ADV TO TRANS TIME
         ASSIGN     4+,V$AV              ADD ADVANCE TO MSG TRANS TIME
         ADVANCE    V$MS                 TIME SPENT IN MEDSP TRANSFER
         RELEASE    6                    RELEASE TRANSMISSION FACILITY
         UNLINK     MEDSP,WAIT2,1          UNLINK 1 MSG FROM QUEUE CHAIN
         TRANSFER   ,LVMMU               TRANSFER TO LVMMU BLOCK
LOSPD    LINK       LOSPD,FIFO,WAIT3       CREATE LOSPD USER CHAIN
WAIT3    SEIZE      7                    SEIZE TRANS FACILITY
```

```
// EXEC COBACLG
//COB.SYSPRINT DD SYSOUT=D
//COB.SYSIN  DD  *
       IDENTIFICATION DIVISICN.
       PROGRAM-ID. 'TRIBUTIL'.
       AUTHOR. R.B.MCMANIS.
       REMARKS. THIS PROGRAM COMPUTES THE TRIB UTILIZATION
           AND OTHER QUEUING INFORMATION FOR USE IN
           DETERMINING ASC TRIB AND TRUNK EFFICIENCY AND
           TO ASCERTAIN THE NEED FOR CHANGES.
       ENVIRONMENT DIVISICN.
       CONFIGURATION SECTION.
       SOURCE-COMPUTER. IBM-360-67.
       OBJECT-COMPUTER. IBM-360-67.
       INPUT-OUTPUT SECTICN.
       FILE-CONTROL.
           SELECT TRIB-FILE ASSIGN TO 'TRIBIN' UTILITY.
           SELECT OUTPUT-FILE ASSIGN TC 'PRINT' UTILITY.
       DATA DIVISION.
       FILE SECTICN.
       FD  TRIB-FILE
           RECORDING MODE IS F
           LABEL RECORDS ARE OMITTED
           RECORD CONTAINS 80 CHARACTERS
           DATA RECORD IS TRIB-REC.
       01  TRIB-REC.
           02  TRIB-NAME         PICTURE X(16).
           02  FILLER            PICTURE X.
           02  TRIB-MODE         PICTURE 9(4).
           02  FILLER            PICTURE X.
           02  NUM-MSG           PICTURE 9(6).
           02  FILLER            PICTURE X.
           02  NUM-LNBLK         PICTURE 9(7).
           02  FILLER            PICTURE X.
           02  NUM-LINES         PICTURE 9.
           02  FILLER            PICTURE X(42).
       FD  OUTPUT-FILE
           RECORDING MODE IS F
           LABEL RECORDS ARE OMITTED
           RECCRC CONTAINS 133 CHARACTERS
           DATA RECORD IS PRINT-LINE.
       01  PRINT-LINE            PICTURE X(133).
       WORKING-STORAGE SECTION.
       77  MIR                   PICTURE 9V9999  VALUE 0.
       77  BPS-CAP               PICTURE 9(4)    VALUE 0.
       77  UTIL                  PICTURE 9V9999  VALUE 0.
       77  MST                   PICTURE 9V9999  VALUE 0.
       77  MNTP                  PICTURE 9V9999  VALUE 0.
```

```
       OPEN-FILES.
           OPEN INPUT TRIB-FILE, OUTPUT OUTPUT-FILE.
           MOVE TITLE-C TO PRINT-LINE.
           WRITE PRINT-LINE AFTER ADVANCING 0 LINES.
           MOVE TITLE-A TO PRINT-LINE.
           WRITE PRINT-LINE AFTER ADVANCING 3 LINES.
           MOVE TITLE-B TO PRINT-LINE.
           WRITE PRINT-LINE AFTER ADVANCING 2 LINES.
           MOVE TITLE-C TO PRINT-LINE.
           WRITE PRINT-LINE AFTER ADVANCING 3 LINES.
           MOVE TITLE-D TO PRINT-LINE.
           WRITE PRINT-LINE AFTER ADVANCING 3 LINES.
           MOVE TITLE-E TO PRINT-LINE.
           WRITE PRINT-LINE AFTER ADVANCING 1 LINES.
       BEGIN.
           READ TRIB-FILE AT END GO TO WRAPUP.
           COMPUTE MIR = NUM-MSG / ((31.0 * 24.0) * (60.0)).
           COMPUTE BPS-CAP = TRIB-MODE * NUM-LINES.
           COMPUTE UTIL = ((NUM-LNBLK * (84.0 * 8.0)) / ((30.0 * 24.0) *
      -     60.0)) / (BPS-CAP * 60.0).
           COMPUTE MST = ((NUM-LNBLK / NUM-MSG) * 640.0) / ((BPS-CAP) *
      -    (60.0)).
           COMPUTE MNTP = UTIL / (1 - UTIL).
           COMPUTE MTIP = MST / (1 - UTIL).
           COMPUTE MTFP = MTIP - MST.
           COMPUTE MNWP = MNTP - UTIL.
           MOVE TRIB-NAME TO NAME-OUT.
           MOVE UTIL TO UTIL-OUT.
           MOVE MIR TO MIR-OUT.
           MOVE MST TO MST-OUT.
           MOVE MNTP TO MNTP-OUT.
           MOVE MTIP TO MTIP-OUT.
           MOVE MTFP TO MTFP-OUT.
           MOVE MNWP TO MNWP-OUT.
           MOVE UTIL-LINE TO PRINT-LINE.
           WRITE PRINT-LINE AFTER ADVANCING 2 LINES.
           GO TO BEGIN.
       WRAPUP.
           CLOSE TRIB-FILE, OUTPUT-FILE.
           STOP RUN.
//GO.PRINT DD SYSOUT=D
//GO.TRIBIN DD *,DCB=BLKSIZE=80
OAKLND ARMY TERM 2400 011329 1275547 1
```

```
77  MTIP                       PICTURE 9V9999   VALUE 0.
77  MTFP                       PICTURE 9V9999   VALUE 0.
77  MNWP                       PICTURE 9V9999   VALUE 0.
01  TITLE-A.
    02  FILLER                 PICTURE X        VALUE SPACES.
    02  HEADER                 PICTURE X(75)    VALUE '
-   '                                             ASC  MC CLELLAN    AFB'.
    02  FILLER                 PICTURE X(57)    VALUE SPACES.
01  TITLE-B.
    02  FILLER                 PICTURE X        VALUE SPACES.
    02  HEADER                 PICTURE X(73)    VALUE '
-   '                                             TRIBUTARY  ANALYSIS'.
    02  FILLER                 PICTURE X(59)    VALUE SPACES.
01  TITLE-C.
    02  FILLER                 PICTURE X        VALUE SPACES.
    02  HEADER                 PICTURE X(132)   VALUE '------------------
-   '---------------------------------------------------------------------
-   '-----------------------------------'.
01  TITLE-D.
    02  FILLER                 PICTURE X        VALUE SPACES.
    02  HEADER                 PICTURE X(117)   VALUE '                 FA
-   'CILITY  MEAN INPUT      MEAN SVC        MEAN NR TRANS   MEAN
-   'TIME IN   MEAN TIME FOR  MEAN NR TRANS'.
    02  FILLER                 PICTURE XX       VALUE SPACES.
01  TITLE-E.
    02  FILLER                 PICTURE X        VALUE SPACES.
    02  HEADER                 PICTURE X(119)   VALUE '    TRIB NAME    UT
-   'IL (.)  RATE (MSG/MIN)  TIME (MIN/MSG)  IN PROCESS       PROCE
-   'SS (MIN)  PROCESS (MIN)  WAIT FOR PROCESS'.
01  UTIL-LINE.
    02  FILLER                 PICTURE X        VALUE SPACES.
    02  NAME-OUT               PICTURE X(16)    VALUE SPACES.
    02  FILLER                 PICTURE XX       VALUE SPACES.
    02  UTIL-OUT               PICTURE 9.9999.
    02  FILLER                 PICTURE X(6)     VALUE SPACES.
    02  MIR-OUT                PICTURE 9.9999.
    02  FILLER                 PICTURE X(10)    VALUE SPACES.
    02  MST-OUT                PICTURE 9.9999.
    02  FILLER                 PICTURE X(10)    VALUE SPACES.
    02  MNTP-OUT               PICTURE 9.9999.
    02  FILLER                 PICTURE X(10)    VALUE SPACES.
    02  MTIP-OUT               PICTURE 9.9999.
    02  FILLER                 PICTURE X(10)    VALUE SPACES.
    02  MTFP-OUT               PICTURE 9.9999.
    02  FILLER                 PICTURE X(10)    VALUE SPACES.
    02  MNWP-OUT               PICTURE 9.9999.
    02  FILLER                 PICTURE X(6)     VALUE SPACES.
PROCEDURE DIVISION.
```

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13. ABSTRACT

A general AUTODIN and Automatic Switching Center (ASC) system description is presented to orient the reader.

A GPSS model of the Communications Data Processor (CDP) at the ASC was constructed, as a first step toward constructing an overall ASC simulation model. The capabilities and limitations of the simulation are discussed. Several experiments were conducted to ascertain the effects on the CDP message congestion and transit time of varying the volume of traffic passing through the system and the number of tributaries capable of receiving traffic.

A COBOL program, which calculates queuing information for the ASC tributaries, is described. The results of the program output are interpreted and uses of the information produced are discussed. Observed problem areas are presented.

Conclusions are drawn concerning the performance of the AUTODIN ASC as shown by the simulation and program. Anticipated project applications are described.

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